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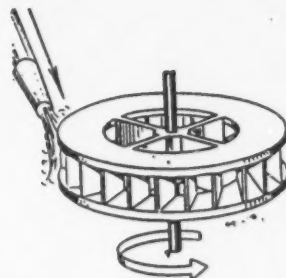
ABSTRACT

The curriculum materials contained in this document were developed through a cooperative effort by educators in the state of Maryland. It was a curriculum project aimed at the meaningful integration of mathematics and science. It is suggested that these materials be used in two significant ways. First, this document can serve as an instructional materials resource collection. An extensive variety of technology topics are covered, with each topic including detailed information sheets identifying the mathematical and scientific principles that could be studied in a technology education activity. Secondly, this document can serve as a materials resource guide. This is accomplished by providing a format and process for the creation of similar classroom instruction materials. Included are the following general topics: (1) anemometers; (2) automotive air conditioning; (3) electrical circuits; (4) engines; (5) computer command control; (6) electromagnets; (7) hydraulics; (8) turbines; (9) incandescent lamps; (10) lasers; (11) microwave ovens; (12) water wheels; (13) solar heating; (14) rocket engines; (15) photovoltaic cells; (16) windmills; (17) transformers; (18) wind tunnels; and (19) wood burning stoves. Each of the specific 62 technology topic entries includes the title, descriptions of the transparencies, science concepts, mathematical concepts, and transparency masters graphically illustrating the topic. A list of additional documents available from the Division of Vocational-Technical Education, Maryland Department of Education is provided. (KR)

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TECHNOLOGY EDUCATION

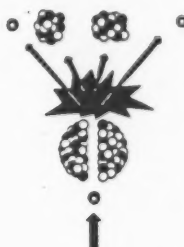


MATHEMATICS AND SCIENCE INTERFACE CURRICULUM PROJECT

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MATH, SCIENCE, TECHNOLOGY EDUCATION INTERFACE



A CURRICULUM PROJECT...

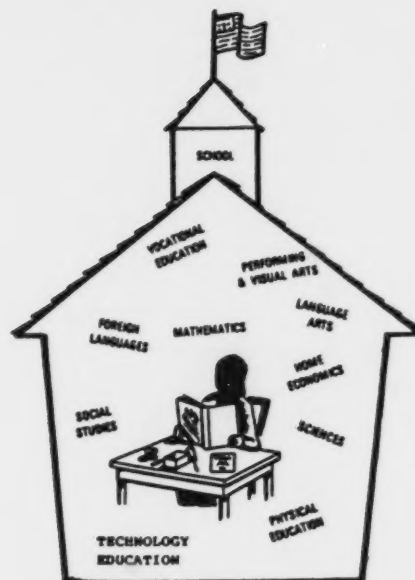
Aimed at enriching the content of industrial arts/technology education as well as demonstrating the potential for this area to make a significant contribution to the students' understanding of mathematics and science in the application of such disciplines in the technology education laboratory.



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THE PURPOSE...



There were four distinct purposes for understanding this project. Each of these have significant value; however, collectively they offer substantial rationale for pursuing holistic learning in our public schools.

They are...

To assist understanding and cooperative relationships in our schools between content areas of mathematics, science and technology education.

To provide for the integration of mathematics and science into the teaching of technology education.

To develop curriculum materials for the integration of mathematics and science into technology education.

To provide inspiration and direction for further content integration for all subjects.



THE PROCESS...



The math/science/technology education project was a cooperative effort by concerned educators in the state of Maryland. It was a curriculum project aimed at enriching the content of technology education through the meaningful integration of mathematics and science. This integration should demonstrate the potential for technology education to make a significant contribution to the students' understanding of these subjects through their application in the technology education laboratory.

The project was conducted over a three year period, beginning in the summer of 1985, continuing in 1986, and concluding in 1987. Each year, teachers from public schools throughout Maryland were assembled for two weeks. The organization was provided by the Department of Industrial, Technological and Occupational Education at the University of Maryland, College Park Campus. During these two week periods, teams of educators were involved in the process of creating technology education instructional materials that integrated the subject areas of mathematics and science. Appropriately, each team represented one school and included one teacher from each of the following areas: Industrial Arts/Technology Education, Math and Science. It was the responsibility of the technology teacher to lead the team by providing direction for content development. As each technology teacher identified the content from his/her program, the science and math teachers would analyze the content for science and math applications. The outcome of this effort was the creation of appropriate visual masters that would communicate technological content as well as applied science and math principles. This master would be supplemented with information sheets carefully developed by the math/science members of the team. The information sheets would describe in greater detail the specific science and mathematics principles related to the technology content topic.

Follow-up activities involved workshops and in-service sessions in each of the local education agencies participating in the project. Finally, these curriculum materials were prepared for distribution to all participants, as well as local education agencies throughout the state.

ACKNOWLEDGEMENTS..

This document is the result of a major cooperative effort over a three period at all educational levels.

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Edited By...

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ACKNOWLEDGEMENTS

Teacher Teams...
(1985)

Arbutus Middle School

Technology Teacher	Steve Bartley
Science Teacher	Linda McCelland
Math Teacher	James Hastings

Calvert High School

Technology Teacher	Carl Fenwick
Science Teacher	Terrance Klazer
Math Teacher	Kevin Michael

Catonsville High School

Technology Teacher	Bill Gibbs
Science Teacher	Buddy Brietenbach
Math Teacher	Ken Berry

Cherry Hill Middle School

Technology Teacher	Wilson Thompson
Science Teacher	Gretchen Lawson
Math Teacher	Kermit Williams

Franklin High School

Technology Teacher	Howard Spears
Science Teacher	Stanislaus Ziolkowski
Math Teacher	Joseph Noto

Gaithersburg High School

Technology Teacher	Willie Hill
Science Teacher	Dr. Donald Poe
Math Teacher	Deno Diamonds

Glen Burnie High School

Technology Teacher	Art Chenowith
Science Teacher	John O'Dell
Math Teacher	Glenna Hilditch

ACKNOWLEDGEMENTS

Teacher Teams...
(1985)

John Hanson Middle School

Technology Teacher	Kenneth L. Smith
Science Teacher	Christine Smith
Math Teacher	Drew Jepsy

North Carroll High School

Technology Teacher	Stephen Shepler
Science Teacher	Dean Packer
Math Teacher	Babette Leister

Sparrows Point Middle School

Technology Teacher	Will Heilman
Science Teacher	Ruth Jensen
Math Teacher	Paul Leimbach

ACKNOWLEDGEMENTS

Teacher Teams...
(1986)

Einstein High School

Technology Teacher	Robert Wotkowski
Science Teacher	Russell Wright
Math Teacher	Mary Carter

John Hanson Middle School

Technology Teacher	Kenneth L. Smith
Science Teacher	Christine Smith
Math Teacher	Drew Jepsy

Oxon Hill High School

Technology Teacher	Charles Algire
Science Teacher	Michael Mickolay
Math Teacher	Diana B. McCusker

Prince George's County Schools

Frank Grahn	George Miles
Robert Gray	Roland Moore
Connie Jones	Nelson Sharpe

Roosevelt High School

Technology Teacher	Joseph Irizarry
Science Teacher	Bobbie Smith
Math Teacher	Mike Reidy

Springbrook High School

Technology Teacher	David Kaplan
Science Teacher	Paul Kroeger
Math Teacher	Regina Skyles

Wilde Lake High School

Technology Teacher	Charles Venable
Science Teacher	Nicholas Zoulias
Math Teacher	Eric Ebersole

Woodlawn Middle School

Technology Teacher	Richard Harbach
Science Teacher	Cheryl Migliarini
Math Teacher	William Gluth

ACKNOWLEDGEMENTS

Teacher Teams...
(1987)

Chesapeake Middle School

Technology Teacher	Thomas Eoannou
Science Teacher	Donald Stenimler
Math Teacher	Dione McManus

Eastern Vocational-Technical School

Vocational Teacher	Earl Crusse
Science Teacher	William Stacy
Math Teacher	Albert Smith

Earle B. Wood Junior High School

Technology Teacher	Mark Green
Science Teacher	Richard Knight
Math Teacher	Julia Pepeta

Galena Middle School

Technology Teacher	Charles Cooper
Science Teacher	Margaret F. Crow
Math Teacher	Kevin Smith

Mergenthaler Vocational-Technical School

Vocational Teacher	Jack Jacobs
Science Teacher	Gail Brayton
Math Teacher	Dwight Evans

North Caroline High School

Technology Teacher	Len Harmon
Science Teacher	Patricia Clay
Math Teacher	Mike Miller

North Carroll Middle School

Technology Teacher	Robert Lenz
Science Teacher	Tim Hontz
Math Teacher	Linda Guillen

ACKNOWLEDGEMENTS

Teacher Teams...
(1987)

Owings Mill High School

Technology Teacher	Roland Phelps
Science Teacher	Sherman Kopelson
Math Teacher	Sharon Oland

Taney Middle School

Technology Teacher	Dennis Hearn
Science Teacher	Bruce Guinn
Math Teacher	John Davis

West Frederick Middle School

Technology Teacher	Paul E. Dunford
Science Teacher	Paula Lawton
Math Teacher	Rose Geiger

CONTENT INTEGRATION

A RATIONALE...

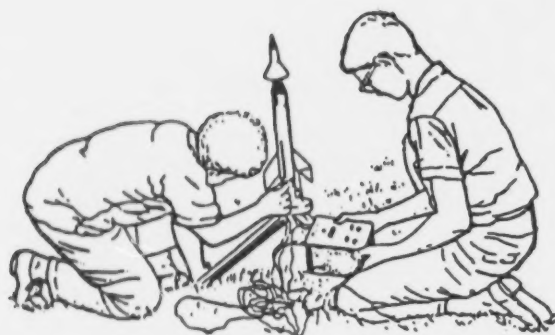


If technology education is to seriously provide for greater understanding and awareness of technological achievement, the issue of holistic learning must be addressed. If one is to truly understand any technological achievement, anthropological or contemporary, a discovery and realization of the specific scientific and mathematical concepts must be accomplished. To illustrate: a student studying rocket technology can use a few tools and machines to build a model of a rocket in any technology education laboratory. However, if that student is to gain a meaningful understanding of rocket propulsion, the scientific and mathematical relationships causing a rocket to function must become part of the instructional activity. Without this effort, the student is involved in a very superficial program.

It is most important to remember that the constructive activity is a vital part of the technology education experience. Generally, constructed items in class serve to motivate students. This motivation can be used to initiate further investigation into a particular curricular topic. Leading a student into a deeper understanding of a "cause and effect" relationship behind a technical device should be a carefully planned and managed instructional process. This process demands the inclusion of science and mathematics; that is, if understanding is the desired outcome.

Technology education offers, within its content and methodology, a prime vehicle through which the subjects of the school can be unified for relevant, meaningful learning on the part of the student. This is particularly true for mathematics and science. Technology education teachers permit students the opportunity to discover through investigation, research and problem solving the "how and why" relationships of science, math and technology education. This approach to subject integration would then continue and enhance the vital "experiential-active" quality that technology education has always valued.

TECHNOLOGY EDUCATION



A DEFINITION...

Technology education is an experienced-based curriculum area in which students study technology... its evolution, utilization and significance. It develops the technological literacy everyone needs. It involves learning experiences, including the application of mathematics and science, in such areas as communications, construction, manufacturing, power and energy, transportation, including the impact of these areas on the environment and society.



TECHNOLOGY EDUCATION



OPPORTUNITIES TO...

Acquire knowledge, understandings and skills needed to function in a technological environment.

Integrate and apply concepts and skills of mathematics, science and communication.

Explore societal and environmental impacts of technology.

Solve problems through laboratory experiences which incorporate creative inquiry, ingenuity, discovery and interaction with technology.



LONG-RANGE OUTCOME...



It is most desirable that this curriculum integration effort will provide direction for not only technology educators, but all concerned educational personnel pursuing meaningful, holistic learning in our public schools. However, as with any curriculum development experience, its usefulness depends on further creation and appropriate implementation by teachers in their classrooms. This body of work has already furnished sufficient guidance for some workshop participants to design and utilize additional materials suitable for use in their particular programs.

It has been convincingly argued that technology education can lead the way for meaningful, relevant subject integration in our schools. The effort in this curriculum project supports that argument. If teachers from the content areas of mathematics, science and technology education can cooperatively discuss, plan, design and produce curriculum materials such as those included in this document, certainly individual schools or local educational agencies should be able to coordinate similar activities. Technology educators should take this opportunity to provide the leadership necessary for further holistic curriculum exploration. Just as leadership and direction was provided by technology educators during this project, continued educational attempts to integrate mathematics and science into the technology education curriculum should be guided by individuals in technology education. The technology laboratories and curricula offer students that place within the school that can bring real understanding to all subjects.

The instructional materials contained in this document serve as examples of successful curriculum integration. The key to this success was carefully managed cooperation among concerned educators. Continued usefulness of these materials will certainly depend on carefully planned and supervised strategies. It is suggested that this document provide the impetus for workshops, seminars and various other in-service activities at all educational levels. The goal... appropriate and meaningful application of mathematics and scientific concepts into technology education.

CLASSROOM USE...



One of the goals of this document is to provide for continued mathematics, science and technology integration. With this in mind, it is suggested that these materials can be used in two significant ways. However, it is important to realize that effective use of this document greatly depends on the initiative of technology teachers, resource teachers and supervisory personnel.

First, this document can serve as an instructional materials resource collection. The teams of educators who participated in the three year workshop have produced an extensive variety of technology topics presented as part of their individual programs. Each topic includes detailed information sheets identifying the mathematical and scientific principles that could be studied in the technology education activity. The quantity and depth of study for these math and science concepts remains at the discretion of the technology teacher. Variations in content usefulness will also depend on individual school or classroom conditions as well as the grade level of students.

Because of the wide range of technology topics presented, many teachers will be able to simply review and select items appropriate for immediate use in the classes. Some will be useful with only minor modifications to subject content. After basic planning and curriculum consideration, most technology teachers should be able to include some of these materials as part of their technology instruction.

Secondly, this document can serve as a materials resource guide. This is accomplished by providing a format and process for the creation of similar classroom instructional materials. It is suggested that after reviewing these materials and understanding the cooperative 'teaming' process used in their creation, technology teachers will adopt a similar approach as they develop classroom materials appropriate to their programs. Although technology teachers generally possess backgrounds in mathematics and science, it is most valuable to pursue the assistance of the school's mathematics and science personnel in the identification of those principles peculiar to their programs. This effort will insure accurate and relevant subject integration with the technology education curriculum. In addition, math and science teachers could also reinforce technology education concepts in their curricula.

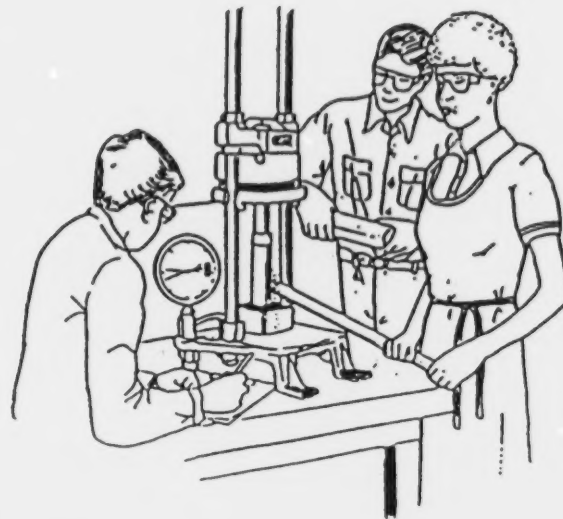


ORGANIZATION...

This document is organized into five categories. These categories are selected from the content areas identified in the definition of technology education.

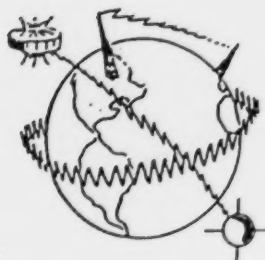
Each technology topic has been placed in the most appropriate content area. However, some topics may be appropriate in more than one area.

Each content category includes a statement of definition and a point of view.

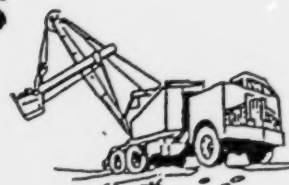


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CONTENT AREAS:



- **COMMUNICATIONS**



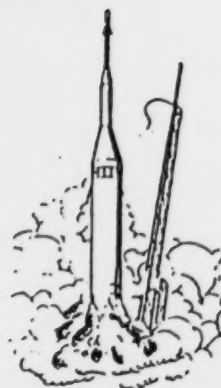
- **CONSTRUCTION**

- **MANUFACTURING**



- **POWER AND ENERGY**

- **TRANSPORTATION**



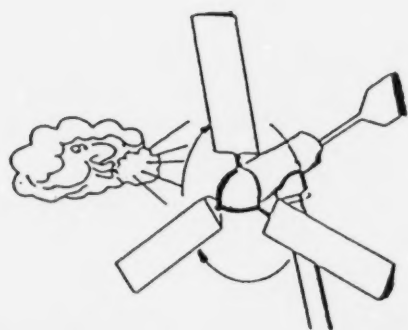
POWER & ENERGY

Point of View...

Our earliest attempts to survive in the environment required a constant search for ways to enhance our limited power. These crude beginnings usually involved using natural materials to create simple tools improving leverage thus reducing the power needed to do some work. Eventually, animals were used to increase power and accomplish substantially larger amounts of work. Slowly, very slowly, discoveries were made and humans began to create more tools and eventually systems of tools-machines. In many instances, these discoveries were quite accidental. However, there were many creations that evolved from very deliberate and applied uses of known scientific principles. As our tasks became more demanding, new devices were created to increase the power necessary to get the job done. Eventually, the steam engine was born and the Industrial Revolution was creating and molding a new society.

It should be obvious that power and energy are the foundations or life blood for all other technologies. All areas of technological concern... communications, construction, manufacturing, and transportation require varying methods of using energy to provide needed power. Without energy and power, it all stops. Considering this revelation, the ability to conserve limited sources and harness new sources of energy is paramount.

Society's enormous appetite for consuming energy and demands for power provide the challenge now and certainly for the future. The key, as with early human effort, will be the ingenious application of scientific and mathematical knowledge in the creation of needed technology. Remember, without the needed power and energy... it all stops!



POWER & ENERGY

AS A CONTENT AREA IS THE STUDY OF THOSE TECHNOLOGIES THAT HARNESS AND USE SOURCES OF ENERGY FOR THE CREATION OF POWER AND TECHNOLOGIES THAT USE POWER TO CREATE CERTAIN FORMS OF ENERGY. INCLUDED ARE APPLICATION CONCEPTS FOR: ENERGY SOURCES, ENERGY CONVERSION AND ENERGY TRANSMISSION.





SOURCES OF ENERGY

SOLAR

MOVING WATER

FOSSIL FUELS

URANIUM

WIND

GEOTHERMAL

HYDROGEN

FUTURE SOURCES

FORMS OF ENERGY

MECHANICAL

HEAT

LIGHT

CHEMICAL

ELECTRICAL

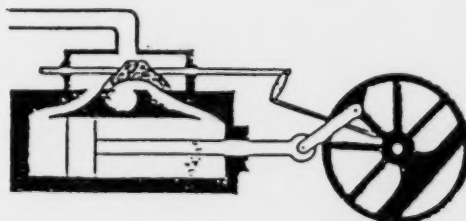
NUCLEAR

POWER SYSTEMS

MECHANICAL

ELECTRICAL

FLUIDIC



POWER & ENERGY

TECHNOLOGY TOPICS

ANEMOMETER	INCANDESCENT LAMP
AUTOMOTIVE AIR CONDITIONING	LASER
ACCUMULATOR	LIFT PUMP
COMPRESSOR	LIGHT EMITTING DIODES
CONDENSER	LOGIC INVERTER
EVAPORATOR	MAGNETIC COMPASS
BASIC ELECTRICAL CIRCUITS	MICROWAVE OVEN
BATTERY	MOVING COIL AMMETER
BIMETAL DEVICES	NEWCOMEN STEAM ENGINE
CARBURETOR	OHM'S LAW
CAPACITORS	OVERSHOT WATER WHEEL
CASTER	PARABOLIC FURNACE
CATALYTIC CONVERTER	PARALLEL CIRCUITRY
COMBUSTION CYCLE	PASSIVE SOLAR HEATING
COMPUTER COMMAND CONTROL	RELATIONSHIP OF VOLTAGE TO BOYLE'S/CHARLES' LAWS
CONDUCTORS	RESISTORS
COPPER WIRE RESISTANCE	ROCKET ENGINES
DIESEL COMPRESSION RATIOS	ROCKETRY
DIODE	SERIES CIRCUITRY
DRY CELL BATTERY	SERIES-PARALLEL CIRCUITRY
ELECTROMAGNETIC FIELD STRENGTH... CORE PERMEABILITY	SILICON PHOTOVOLTAIC CELL
ELECTROMAGNETIC RELAY	SIMPLE MACHINES
ELECTROMAGNETS	SMOCK WINDMILL
ELECTRON BEAM DEFLECTION	SOLAR ENERGY
ELECTRONIC MAZE	SOLAR HEATER
FLYBALL GOVERNOR	SOLAR WATER HEATER
FOUR STROKE ENGINE	TRANSFORMERS
FULL WAVE RECTIFICATION	TRANSISTOR OPERATION
GEARS	TURBOCHARGING
HALF WAVE RECTIFICATION	TWO STROKE ENGINE
HYDRAULICS	WIND TUNNEL
IMPULSE STEAM TURBINE	WIND TURBINE
IMPULSE WATER TURBINE	WOOD BURNING STOVE

ADDITIONAL DOCUMENTS

The following documents are also available from the Division of Vocational-Technical Education, Maryland State Department of Education.

MANUFACTURING

BANDSAW
BICYCLE FRAME BRAZING
BLIND POP RIVETING
BOARD FOOTAGE
BUFFING WHEEL
DESIGN AND CONSTRUCTION-FIBERGLASS BOAT
DIP MOLDING
DRILLPRESS
DRILLS
ELECTRIC SPOT WELDING
INJECTION MOLDING
JIGSAW
LASER DRILLING-WELDING
LATHE CUTTING SPEEDS
MICROMETER
OXYGEN-ACETYLENE TORCH
ROTATIONAL MOLDING
SOLDERING
THERMOFORMING
TIN SNIPS
WOOD FINISHES
WOOD LAMINATING
WOOD STAINS
WOOD TURNING
WOOD WAXES

COMMUNICATIONS

BELL'S LIQUID TELEPHONE
CAMERA
CRYSTAL RADIO
DYNAMIC MICROPHONE
EARLY RADIO
EARLY TELEVISION
EDISON'S PHONOGRAPH
FIBER OPTICS
HOLOGRAPHY
LIGHTHOUSE
PERISCOPE
PHONOGRAPH
PHOTO ENLARGER
PINHOLE CAMERA
PRINTING PRESS
PROBLEM SOLVING
RADAR
RADIO SYSTEMS
SATELLITE TELEVISION
SPEAKER CONSTRUCTION
SUNDIAL
TELEGRAPH
TELEPHONE OPERATION
TELESCOPE
TELEVISION CAMERA

CONSTRUCTION

ABRASIVE TECHNOLOGY
ARCHITECTURAL MATERIALS UNDER COMPRESSION LOAD
BENDING WOOD
BRIDGE CONSTRUCTION
BRIDGE TRUSS
CHARPY IMPACT TESTING
CONCRETE STRENGTH
COPPER ELECTROPLATING
DECK CONSTRUCTION
DIMENSIONAL CHANGE IN WOOD
HAMMER
HARDENING OF STEEL
HEAT TREATING METALS
HOUSE CONSTRUCTION
JOINING WITH SILVER SOLDER
WATER JOINTS
MAILING
ROOF FRAMING
SCREWDRIVER
STEEL
TRUSSES
WALL INSULATION

TRANSPORTATION

BELL XP-59A AIRACOMET...FIRST AMERICAN JET
CANAL LOCK
CONESTOGA WAGON
GODDARD'S LIQUID FUEL ROCKET
HOT AIR BALLOON
MAGNETIC LEVITATION TRAIN (MAGLEV)
METRIC DRAGSTER
OPERATION SAIL
REACTION ENGINE CAR
WRIGHT BROTHERS AIRPLANE

XXIV

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Title: Anemometer

Category: Energy and Transportation Technology

Description:

Students explore the cause and behavior of wind through construction of wind speed indicators. The instrument - an anemometer - consists of three or more cups mounted on arms which are connected to the same shaft. The force of the wind pushing against the insides of the cups causes the shaft to rotate. Students experiment in cup design in light of efficiency and aesthetics.

Supplementary lab stations may include tracing air currents in convection boxes, plastics molding, and demonstrations of air expansion due to heat. Students engage in varied activities as they evaluate the performance of the instrument. These pursuits include estimation, instrument calibration, calculation, and the use of descriptive language to evaluate numerical readings.

Title: Anemometer

Category: Energy and Transportation Technology

Science Concepts:

1. A mass of air that moves parallel to the surface of the earth is wind.
2. Three natural events cause winds.
 - * rotation of the earth
 - * unequal heating of land and water
 - * differences in temperature of the atmosphere
3. The Coriolis Force is the apparent force that causes moving bodies on or near the earth's surface to be turned from a straight line.
4. Heated air expands, grows lighter, and rises and cooler air rushes in to replace it.
5. The upward movement of warm air and the downward movement of cool air results in convection currents.
6. Air tends to move from land to ocean at night when the land is cooler.
7. During the day, movement is from ocean to land because the ocean is cooler.
8. The urban, rural, and coastal ecosystems may differ in wind patterns. This is due to proximity to water, building placement, natural shading or pollutants introduced from industry and mass transit.
9. Winds are important because they can transport large quantities of heat and moisture.
10. Wind speed is measured by an instrument called an anemometer.

Title: Anemometer

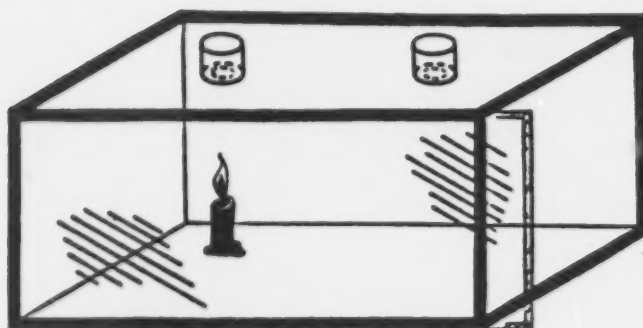
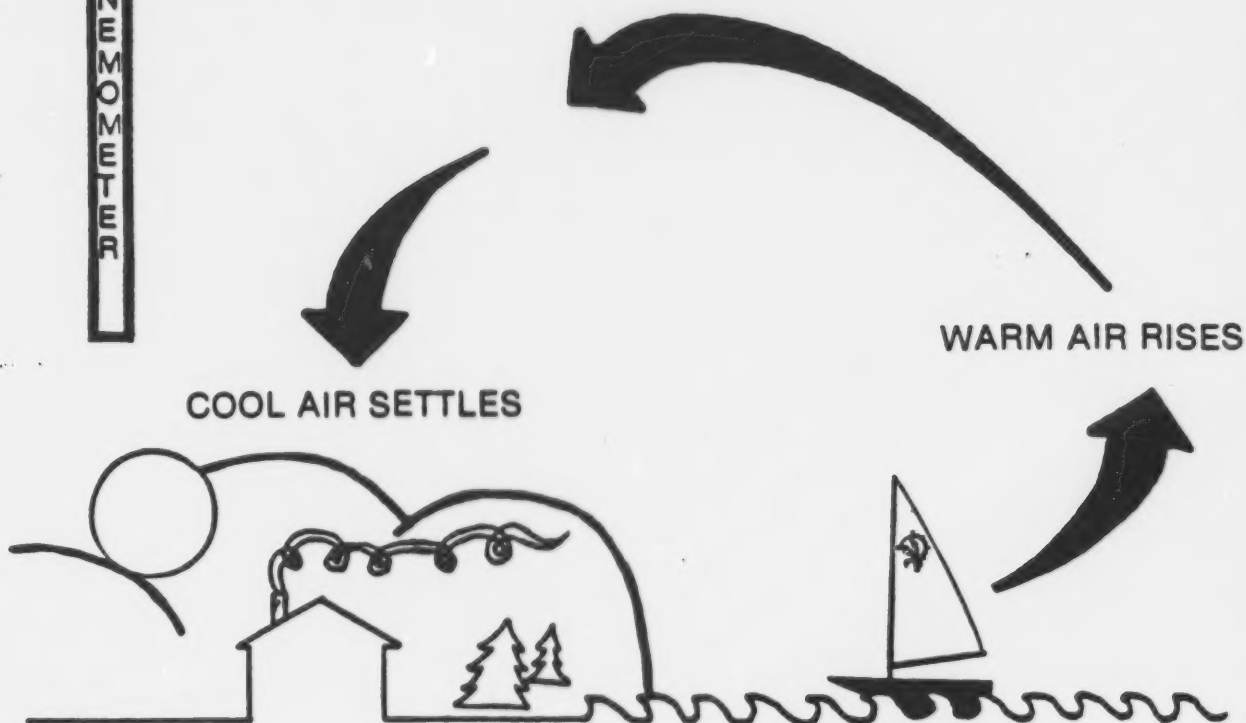
Category: Energy and Transportation Technology

Math Concepts:

1. Estimate the speed of the wind in kilometers per hour $\approx$ the number of revolutions in 30 seconds $\div 5$.
2. $V = (\pi \cdot D) \times (\text{r.p.m.} \times 60)$
Velocity = (pi x diameter)
x (number of revolutions
in one minute x 60 minutes)
3. $C = \pi \times d$
 $C = 2 \times \pi \times r$
Circumference = pi x diameter
Circumference = 2 x pi x radius
4. Graphs
Students will measure, record, and graph the wind speed over a period of days.
5. Multiplication/Division of decimals
6. Measurement
7. Estimation
8. Students distinguish between a gauge and a numerical reading.



ANEMOMETER

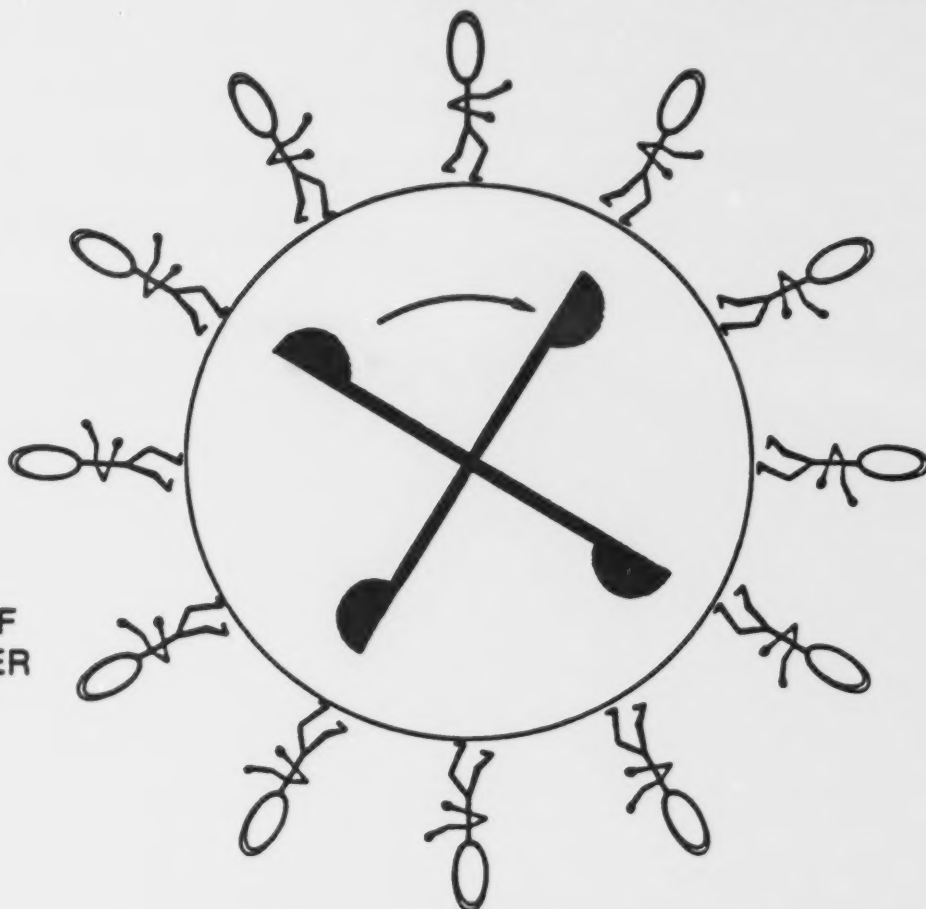


CONVECTION BOX



ANEMOMETER

VELOCITY = WIND SPEED



MOVEMENT OF
ANEMOMETER

VELOCITY = $(\pi \times \text{DIAMETER}) \times (\text{REVOLUTIONS IN ONE MINUTE} \times 60 \text{ MINUTES})$

$$V = (\pi \times D) \times (\text{r.p.m.} \times 60)$$

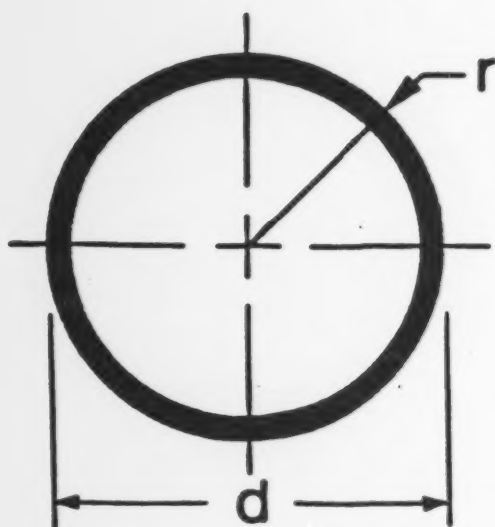
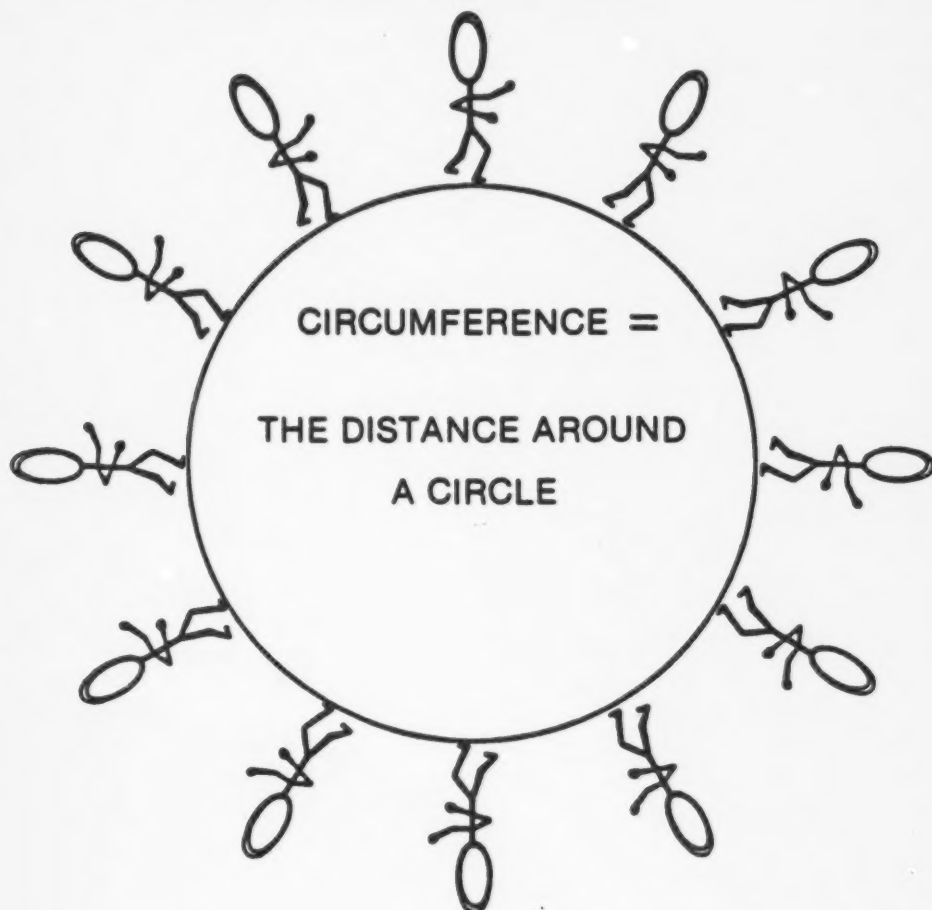
TO ESTIMATE WIND SPEED

KILOMETERS PER HOUR $\approx$

NUMBER OF REVOLUTIONS IN 30 SECONDS $\div 5$



ANEMOMETER



$$\text{CIRCUMFERENCE} = \pi \times \text{DIAMETER}$$

$$C = \pi \times d$$

$$\text{CIRCUMFERENCE} = 2 \times \pi \times \text{RADIUS}$$

$$C = 2 \times \pi \times r$$

Title: Automobile Air Conditioning

Category: System

Description:

Air conditioning is the process used to remove unwanted heat from air as well as cleaning and circulating the resultant product. In addition to those items it also involves the control of quantity and quality of the distributed air.

Air conditioning is a relatively new science which is about 75 years old. It appeared first in the home in the early 20's. Auto air conditioning first appeared in 1927. This first attempt was not well done. In 1940, however, it became an option in the Packard automobile line. It has grown steadily in its use and applications.

The automobile has become a way of life for the modern world. Almost 80% of all cars produced today have air conditioning as part of their standard features. Its applications have allowed the auto occupants to ride in relative comfort and a healthier atmosphere. Its use has helped the operators of the automobile to avoid the pollutants of the highways. The air conditioning system has become an intergral part of today's form of transportation.

Title: Air Conditioning

Category: System

Science Concepts

Pressure: The force acting on a given surface area. Pressure varies with changes in volume, temperature or mass of the coolant.

Pascal's Law: A fluid confined in a container that is completely filled transmits a pressure exerted on the fluid equally to all surfaces of the container. The fluid coolant in an air conditioning system is effectively filling and is confined to, its container.

Incompressibility of liquids: A quantity of liquid cannot be squeezed into a smaller space, regardless of the pressure applied. Pascal's Law depends upon this property.

Density: The mass (or weight) per unit volume of a substance. If the substance is a refrigerant, the density is commonly expressed in pounds per square foot. Ammonia, for example, has a very low density compared to other refrigerants.

Specific Gravity: The density of a substance compared to the density of water. Specific gravity can be used as an indicator of refrigerant purity or water content.

Compressibility: The degree of volume reduction of a gas in response to an increase in the pressure on a given mass of that gas. The compressor pumps a vaporized refrigerant out of the evaporator and compresses it into the condenser.

Boyles' Law: Given a constant gas temperature, the absolute pressure on a mass of that gas varies inversely with the changes in volume. This law is used to predict elevated pressures to be expected with a reduction in volume within the compressor.

Title: Air Conditioning

Category: System

Science Concepts

Absolute pressure: Units of pressure developed from a comparison to the pressure within a vacuum indicated by zero pounds per square inch.

Absolute pressures are used in conjunction with Boyles' Law.

Gage pressure: Units developed from a comparison to the atmospheric pressure indicated as zero pounds per square inch. Actual measurements made of air conditioning systems have designed specifications requiring gage pressure measurements.

Heat

Internal energy: The total potential and kinetic energy in the molecules of a substance. The quantity of internal energy in relation to the volume of a container or the mass of the material determines the internal pressures within the air conditioning system.

Heat: The amount of internal energy that flows from one substance to another. Changes in phase direct this flow in the evaporation and condenser stages of refrigeration by the creation of heat sources and heat sinks.

Temperature: A measure of the average kinetic energy of the molecules of a substance. Differences in temperature are required for heat to flow into or out of the refrigeration system.

The first law of thermodynamics: All the heat added to a closed system can be accounted for as mechanical work, an increase in thermal energy, or both. The mechanical energy of the compressor is converted into higher temperatures and pressures within the circulating refrigerant.

The second law of thermodynamics: The entropy of the universe never decreases; during any process, the entropy either remains constant or else increases. The effective application to heating and cooling systems is the idea that heat flows from higher temperature objects to lower

Title: Air Conditioning

Category: System

Science Concepts

temperature objects.

Conduction: The transfer of heat energy from one end of a body to the other or from one object to another, through direct contact. Heat must be conducted into and out of the air conditioning system through the containers of the evaporator and condenser.

Radiation: The transfer of heat energy by means of electromagnetic waves. The amount of heat to be removed from an auto interior depends on the degree of absorption or reflection of radiant energy from external sources.

Specific heat: The amount of heat that must be added or subtracted from one gram of a substance to change its temperature one degree Celsius. The specific heat of liquid refrigerants varies considerably depending on the pressure imposed upon them.

Heat of vaporization: The amount of heat required to change one gram of a substance from a liquid to a vapor or vapor to liquid. The capacity of the refrigerant to absorb or release heat will in part depend on this physical property.

Humidity: The amount of water vapor in the air. The effect of cooling the air within the auto will be to remove water vapor by condensation.

Relative humidity: The percentage of water vapor actually present in the air compared to the maximum amount that could be present at a given temperature. As the air is cooled the relative humidity usually drops as well.

Title: Automotive Air Conditioning

Category: Systems

Math Concepts

1. $P = \frac{F}{A}$ Pressure = $\frac{\text{Force}}{\text{Area}}$ $\frac{\text{lb.}}{\text{in.}^2}$ (psi) or $\frac{\text{Newtons}}{\text{m}^2}$ (Pa)

2. $\frac{F_1}{A_1} = \frac{F_2}{A_2}$ $\frac{\text{Force (1)}}{\text{Area (1)}} = \frac{\text{Force (2)}}{\text{Area (2)}}$

F_1, F_2 are the forces at conditions one and two in lb. or Newtons

A_1, A_2 are the areas at conditions one and two in in.^2 or m^2

3. $D = \frac{W}{V}$ Density = $\frac{\text{weight}}{\text{volume}}$ $\frac{\text{lb.}}{\text{in.}^3}$

4. $\text{S.G.} = \frac{D_s}{D_w}$ Specific Gravity = $\frac{\text{Density of the substance}}{\text{Density of water}}$

5. $P_{\text{absolute}} = P_{\text{gage}} + 14.7 \text{ lb./in.}^2$ $P_{\text{absolute}} = \text{Pressure (absolute)}$
 $P_{\text{gage}} = \text{Pressure (gage)}$

6. $P_{\text{absolute}} = P_{\text{gage}} + 101 \text{ KPa}$ $P_{\text{absolute}} = \text{Pressure (absolute)}$
 $P_{\text{gage}} = \text{Pressure (gage)}$

7. $\frac{P_2}{P_1} = \frac{V_1}{V_2}$ $\frac{\text{Pressure (2)}}{\text{Pressure (1)}} = \frac{\text{Volume (1)}}{\text{Volume (2)}}$

P_1, P_2 are the pressures at conditions one and two in lb/in.^2 or Pa

V_1, V_2 are the volumes at conditions one and two in in.^3 or m^3

Note: Pressures are absolute and temperature is constant.

8. $T_k = T_c + 273$ Temperature (Kelvin) = Temperature (Celsius) + 273

T_k represents absolute temperature

9. $\frac{V_1}{V_2} = \frac{T_1}{T_2}$ $\frac{\text{Volume (1)}}{\text{Volume (2)}} = \frac{\text{Temperature (1)}}{\text{Temperature (2)}}$

V_1, V_2 are the volumes at conditions one and two in in.^3 or m^3

T_1, T_2 are the temperatures at conditions one and two in T_k

Note: The pressure is constant.

Title: Automotive Air Conditioning

Category: Systems

Math Concepts

10. $\frac{P_1 V_1}{T_1} = \frac{P_2 V_2}{T_2}$ $\frac{\text{pressure (1)} \times \text{Volume (1)}}{\text{Temperature (1)}} = \frac{\text{pressure (2)} \times \text{Volume (2)}}{\text{Temperature (2)}}$

P_1, P_2 are the pressures at conditions one and two in lb./in.² or Pa

V_1, V_2 are the volumes at conditions one and two in in.³ or m³

T_1, T_2 are the temperatures at conditions one and two in T_k

Note: Pressures and temperatures must be in absolute values.

11. $A = \frac{\pi D^2}{4}$ Area of Circle = $\frac{\pi \times \text{Diameter}^2}{4}$

12. $R_f = VA$ Flow rate (Volume per minute) = Velocity (ft./min.) x A (ft.²)

13. $\frac{Q}{\text{hr.}} = KA \Delta T$

Heat lost per hr. (Btu/hr) = heat conductivity x area x temp. difference in F°

14. Division of decimals

15. Multiplication of decimals

16. Solving proportions

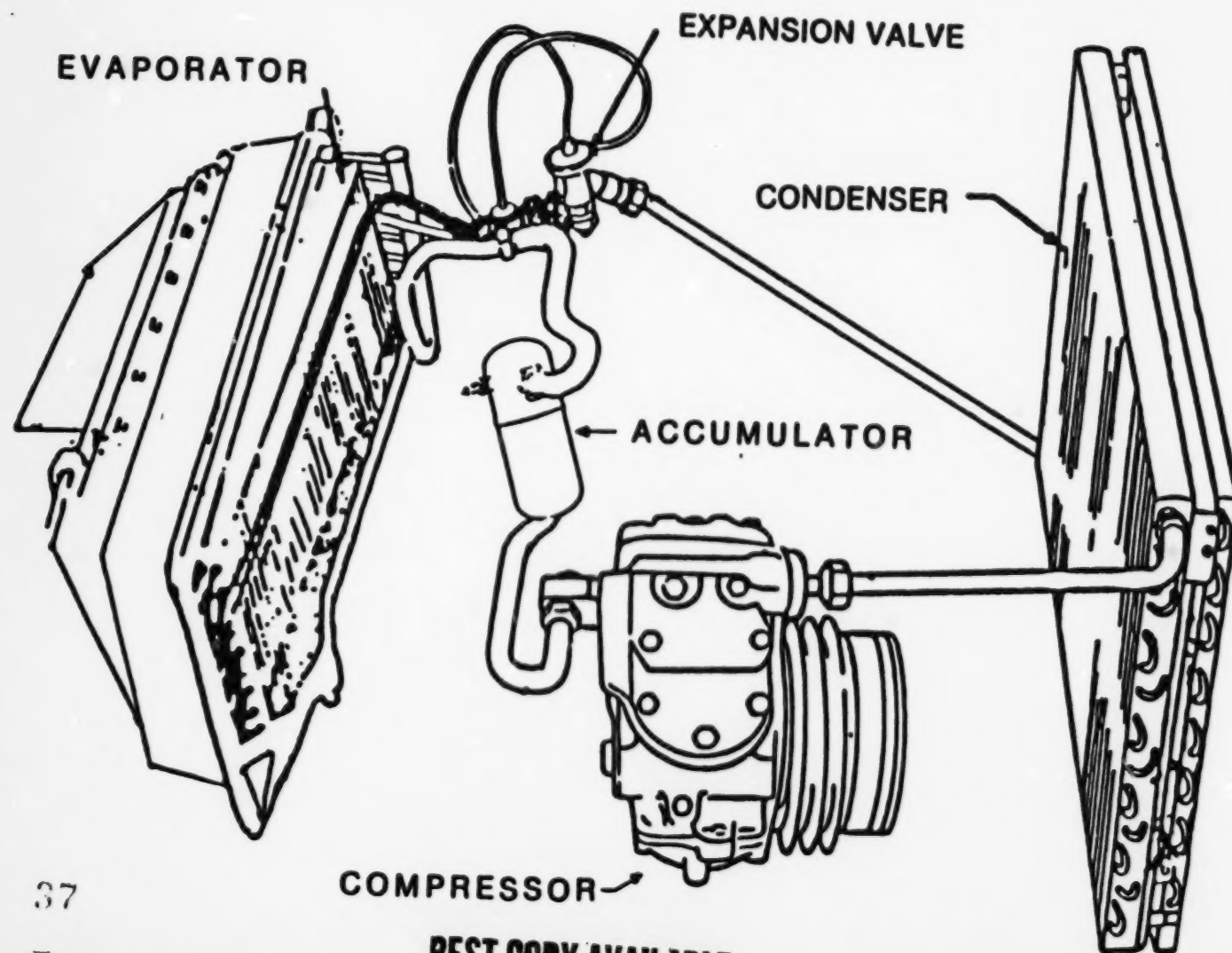
17. Adding integers

18. Solving equations

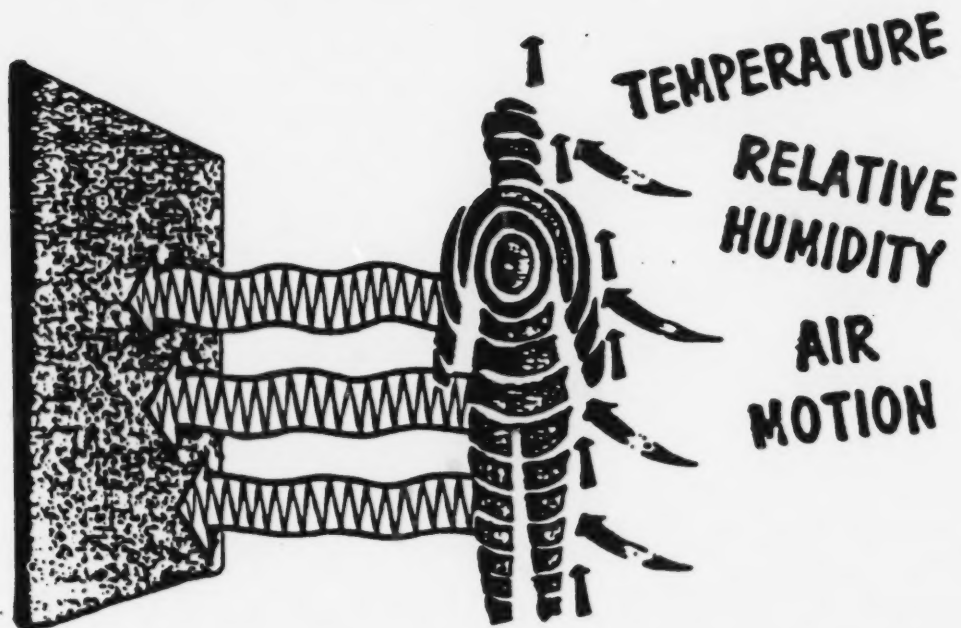
19. Squaring a number

20. Adding decimals

AUTOMOTIVE AIR CONDITIONING



PERSONAL COMFORT



CHARLES' LAW

$$\frac{V_1}{V_2} = \frac{T_1}{T_2}$$

BOYLE'S LAW

$$\frac{P_2}{P_1} = \frac{V_1}{V_2}$$

PASCAL'S LAW

$$\frac{F_1}{A_1} = \frac{F_2}{A_2}$$

Title: Accumulator

Category: System

Description:

The accumulator is an integral part of the air conditioning system. Its function in most automotive systems is two fold in nature. It is located between the evaporator and the condenser. The accumulator receives low pressure gases and liquid from the evaporator to create discharge of only gases to the compressor.

The primary function of the accumulator is to insure the delivery of gases, devoid of liquids to the compressor. When liquid escapes the evaporator in volume, the accumulator receives the low pressure charge and causes only the gaseous product to be transported to the compressor. There is a bleed hole and screen present to allow the oil in the system to continue to circulate to the compressor. The efficiency of the system is closely related to the ability of the accumulator to separate the liquid from the gaseous product which is delivered to the compressor.

The second operation is the removal of moisture which may be present in the refrigerant. A packet of desiccant is used for this purpose. Moisture should be at a minimum for this closed system which will allow desiccation to be carried on for an indefinite time.

When the accumulator becomes inoperative it must be replaced. It is not a component which can be serviced. Some of the accumulator's function is a substitution for that of the receiver drier used in older models.

Title: Accumulator

Category: Processes

Science Concepts:

1. Compressibility: Compressors are designed to compress vapors, not liquids. The accumulator removes the large quantities of liquid.
2. Flow resistance: The suction line carrying the refrigerant must encounter a minimum of resistance.
3. Slope: The suction line must slope from the accumulator to compressor to prevent build up of oil pockets.
4. Pressure changes: The pressure drop across an accumulator is low.
5. Temperature range: Temperatures from -50° to $+40^{\circ}\text{F}$ would be adequate for all commercial applications of the refrigerant in the accumulator.
6. Freezing point: The temperature required to keep separated oil from solidifying narrows the practical minimum temperature to $0-10^{\circ}\text{F}$.
7. Boyle's Law: Given a constant temperature, the pressure varies inversely with the volume of the gas. Since the tubing in the accumulator is of fairly constant volume, pressure change is low.
8. Dilution effects: Liquid refrigerant returned to compressors can dilute lubricating oil and wash out bearings.
9. Friction effects: Diluted lubricating oil can result in too much surface interaction causing broken valve reeds and damage to pistons, rods, crankshafts and other moving parts.
10. Specific gravity: The relative densities of the gaseous refrigerant, liquid and oil determine their location within the accumulator, allowing separation.
11. Archimedes' principle: The lower specific gravity of oil relative to the liquid refrigerant in the accumulator results in a pattern of displacement allowing the floating oil to be returned to the compressor in the proper amounts through the bleed hole.

Title: Accumulator

Category: Processes

Science Concepts:

12. Desiccation: A material which removes water from a system is a desiccant. Silicon gel, activated alumina and synthetic silicates are examples of drying chemicals which can be used in an accumulator.

Math Concepts

1. $p = \frac{F}{A}$ Pressure = $\frac{\text{Force}}{\text{Area}}$ $\frac{\text{lb.}}{\text{in.}^2}$ (psi) or $\frac{\text{Newtons}}{\text{m}^2}$ (Pa)

2. $\frac{P_2}{P_1} = \frac{V_1}{V_2}$ $\frac{\text{Pressure (2)}}{\text{Pressure (1)}} = \frac{\text{Volume (1)}}{\text{Volume (2)}}$

P_1, P_2 are the pressures at conditions one and two in lb./in.^2 or Pa

V_1, V_2 are the volumes at conditions one and two in in.^3 or m^3

Note: Pressures are absolute and the temperature is constant.

3. $P \text{ absolute} = P \text{ gage} + 14.7 \text{ lb./in.}^2$

Pressure (absolute) = Pressure (gage) + 14.7 lb./in.^2

4. $P \text{ absolute} = P \text{ gage} + 101 \text{ KPa}$
Pressure (absolute) = Pressure (gage) + 101 KPa

5. $D = \frac{w}{v}$ Density = $\frac{\text{weight}}{\text{volume}}$ $\frac{\text{lb.}}{\text{in.}^3}$

6. $S.G. = \frac{D_s}{D_w}$ Specific Gravity = $\frac{\text{Density of the substance}}{\text{Density of water}}$

7. $f = uw$ force of friction = coefficient of friction x weight

8. $m = \frac{\Delta y}{\Delta x}$ slope = $\frac{\text{change in vertical distance}}{\text{change in horizontal distance}}$

9. $R_f = VA$ Flow rate (Volume per minute) = Velocity (ft./min.) x Area (ft.^2)

Note: Area = $\frac{\pi \times \text{Diameter}^2}{4}$

10. $F_B = F_2 - F_1$ Buoyant Force = Upward Force - Downward Force

If $F_B > 0$ the object will float

If $F_B = 0$ the object will float at the water level

If $F_B < 0$ the object will sink

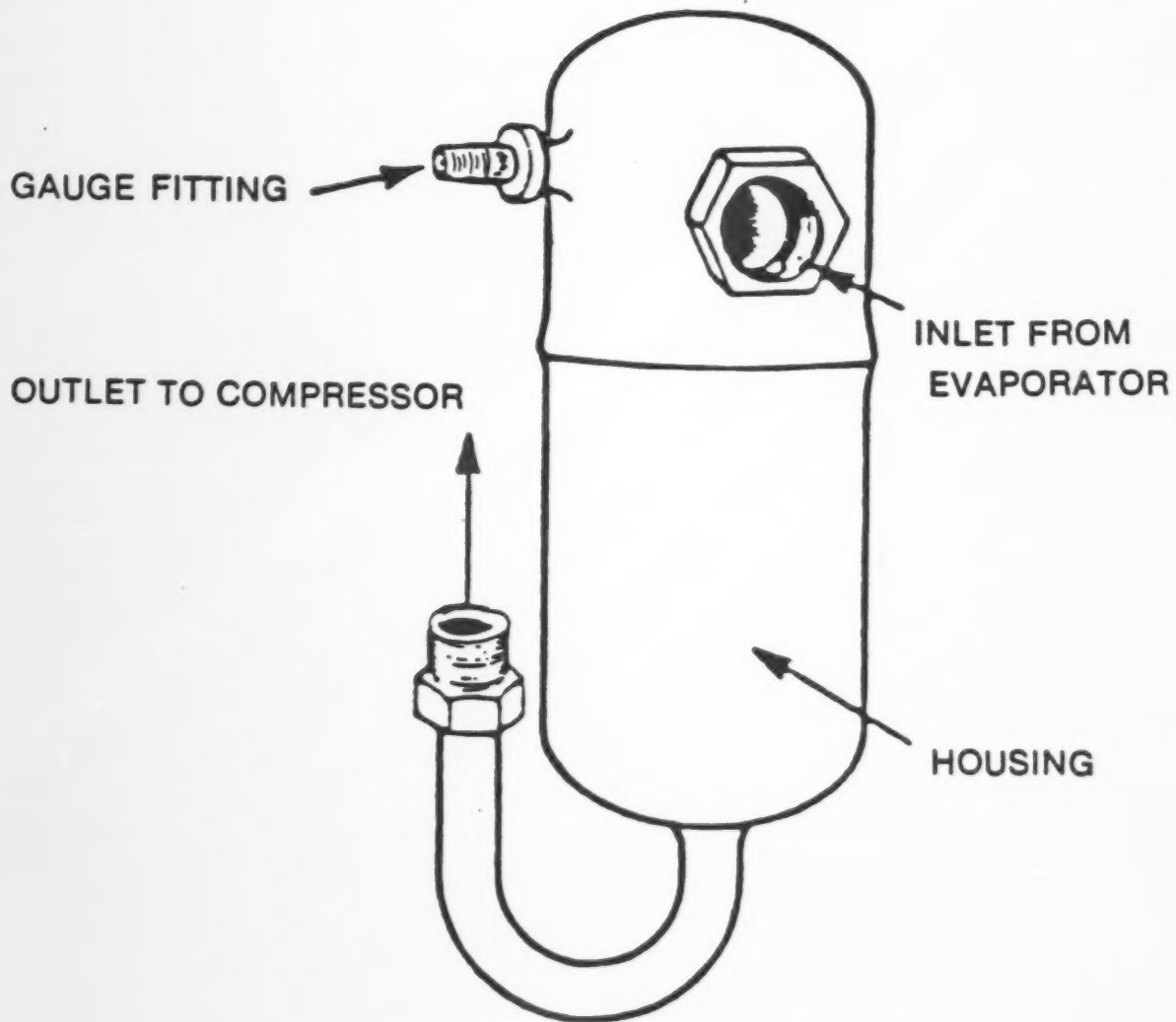
Title: Accumulator

Category: Systems

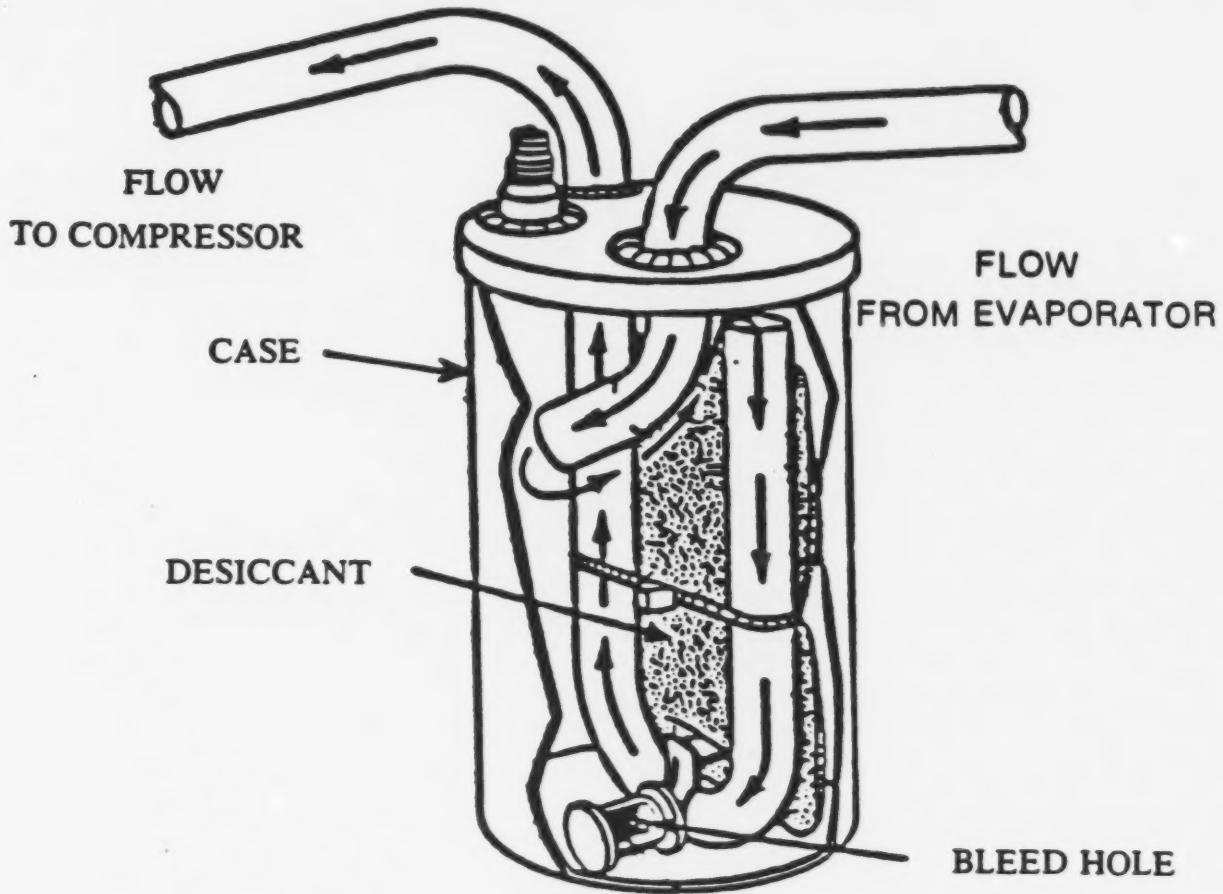
Math Concepts

11. Division of decimals
12. Multiplication of decimals
13. Solving proportions
14. Subtracting integers
15. Adding integers
16. Comparing integers
17. Squaring a number
18. Adding decimals

ACCUMULATOR



FLUID CONTROL



SPECIFIC GRAVITY

$$\text{S.G.} = \frac{\text{DENSITY OF THE SUBSTANCE}}{\text{DENSITY OF WATER}}$$

ARCHIMEDES' PRINCIPLE

BUOYANT FORCE = UPWARD FORCE - DOWNWARD FORCE

FLOW RATE

$$R_f = \text{VELOCITY} \times \text{AREA}$$

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Title: Compressor

Category: System

Description:

The compressor in the automobile air-conditioning system serves two important functions at the same time. One function is to create a low pressure condition at the compressor inlet to remove heated refrigerant vapor from the evaporator. The second function of the compressor is to compress the low-pressure refrigerant vapor into a high pressure vapor. Failure of either function will result in a loss or reduction of circulation of the refrigerant within the system.

As the automobile speeds up, the capacity of the compressor will increase. As it slows down, capacity will decrease. The system must have enough capacity to provide sufficient cooling at idling speed on the hottest day, in the sun, and under side-wind conditions.

Refrigeration compressors can be classified by their number of cylinders, method of compression, type of drive and the location of the driving force or motor. Most automotive air-conditioning compressors are of the reciprocating type. The compressor for an automotive air-conditioning unit is mounted under the hood in the engine compartment. The compressor is belt driven by the engine crankshaft by use of a clutch pulley assembly. The weight and power requirements of the compressor are the most critical factors in the consideration of the air conditioning systems effect on fuel economy.

Title: Compressor

Category: System

Science Concepts:

1. PRESSURE - The sum of bombarding molecules. During compression the pressure increases.
2. BOYLE's LAW - Pressure is inversely proportional to change in volume. This law predicts the degree of pressure increase in the compressor.
3. TEMPERATURE - The speed of molecular motion. During compression, temperature increases.
4. CHARLES' LAW - Temperature is directly proportional to changes in pressure. This law predicts the degree of temperature increase during compression.
5. PRESSURE GAUGES - The measurement of pressure changes is necessary for regulation and repair of the compressor. Gauges can be high pressure, vacuum or a combination of these two types.
6. PRESSURE MEASUREMENTS - Scales and units of measure utilized in pressure measurement include inches of mercury (inHg), pounds per square inch absolute (psia), millimeter of mercury (mmHg) or for very high vacuum, torrs or microns.
7. COMPRESSION RATIO - The compression ratio in the compressor is the relationship of the absolute pressure of the low side to the absolute pressure of the high-pressure side to the total volume of the cylinder.
8. COMPRESSOR VOLUMETRIC EFFICIENCY - The actual volume of refrigerant gas pumped, divided by the calculated volume. For efficient operation, the volumetric efficiency must be as high as possible.
9. COMPRESSOR CAPACITY - The compressor should be just large enough to handle the necessary amount of refrigeration. If the compressor volume is too large,

Title: Compressor

Category: System

Science Concepts:

energy is lost in excess friction. If the compressor is too small, it will not produce the desired refrigeration.

10. EVACUATION - A system opened for any type of repair must be completely evacuated to remove air and moisture. Removing air requires the use of vacuum pumps and periodic recharging with refrigerant vapor. Removing moisture requires the elevation of temperatures in the compressor to evaporate unwanted water.
11. PULLEYS - Compressors can be driven by the use of pulley systems connected to an assortment rotating mechanism such as the crankshaft, waterpumps, alternator or air pump.
12. ELECTROMAGNETISM - All automotive air-conditioning compressors have an electromagnetic clutch attached to their crankshaft or main shaft. This clutch is utilized in starting or stopping the compressor.

Title: Compressor

Category: Systems

Math Concepts

$$1. \frac{p_2}{p_1} = \frac{V_1}{V_2} \quad \frac{\text{pressure (2)}}{\text{pressure (1)}} = \frac{\text{Volume (1)}}{\text{Volume (2)}}$$

p_1, p_2 are the pressures at conditions one and two in lb./in.² or Pa

V_1, V_2 are the volumes at conditions one and two in in.³ or m³

Note: Pressures are absolute and the temperature is constant.

$$2. P \text{ absolute} = P \text{ gage} + 14.7 \text{ lb./in.}^2$$

$$\text{Pressure (absolute)} = \text{Pressure (gage)} + 14.7 \text{ lb./in.}^2$$

$$3. P \text{ absolute} = P \text{ gage} + 101 \text{ kPa}$$

$$\text{Pressure (absolute)} = \text{Pressure (gage)} + 101 \text{ kPa}$$

$$4. \frac{V_1}{V_2} = \frac{T_1}{T_2} \quad \frac{\text{Volume (1)}}{\text{Volume (2)}} = \frac{\text{Temperature (1)}}{\text{Temperature (2)}}$$

V_1, V_2 are the volumes at conditions one and two in in.³ or m³

T_1, T_2 are the temperatures at conditions one and two in T_k

Note: The pressure is constant

$$5. T_k = T_c + 273 \quad \text{Temperature (kelvin)} = \text{Temperature (Celsius)} + 273$$

T_k represents absolute temperature

$$6. \frac{p_1 V_1}{T_1} = \frac{p_2 V_2}{T_2} \quad \frac{\text{pressure (1)} \times \text{Volume (1)}}{\text{Temperature (1)}} = \frac{\text{pressure (2)} \times \text{Volume (2)}}{\text{Temperature (2)}}$$

p_1, p_2 are the pressures at conditions one and two in lb./in.² or Pa

V_1, V_2 are the volumes at conditions one and two in in.³ or m³

T_1, T_2 are the temperatures at conditions one and two in T_k

Note: Pressure and Temperature must be in absolute values.

$$7. \text{Compression ratio} = \frac{\text{absolute pressure of the low side}}{\frac{\text{absolute pressure of the high side}}{\text{total volume of the cylinder}}}$$

Title: Compressor

Category: Systems

Math Concepts

8. Total Volume of the cylinder = $\pi r^2 S_1 + \pi r^2 S_2 + V_p$

r = radius of the cylinder

S_1 = stroke

S_2 = clearance space

V_p = Volume in the valve ports

9. Compressor Volumetric Efficiency = $\frac{\text{actual volume of refrigerant gas pumped}}{\text{calculated volume}}$

10. $V = \frac{\pi D^2}{4} \times S \times N \times R$

Volume = $\frac{\pi \times \text{Diameter}^2}{4} \times \text{length of stroke} \times \text{no. of cylinders} \times \text{rpm}$

11. $Ma = \frac{F_o}{F_i}$ Mechanical Advantage = $\frac{\text{output force}}{\text{input force}}$

12. $\frac{D_1}{D_2} = \frac{R_2}{R_1}$ $\frac{\text{Diameter of Pulley (1)}}{\text{Diameter of Pulley (2)}} = \frac{\text{RPM of Pulley (2)}}{\text{RPM of Pulley (1)}}$

13. Division of decimals

14. Multiplication of decimals

15. Solving proportions

16. Complex fractions

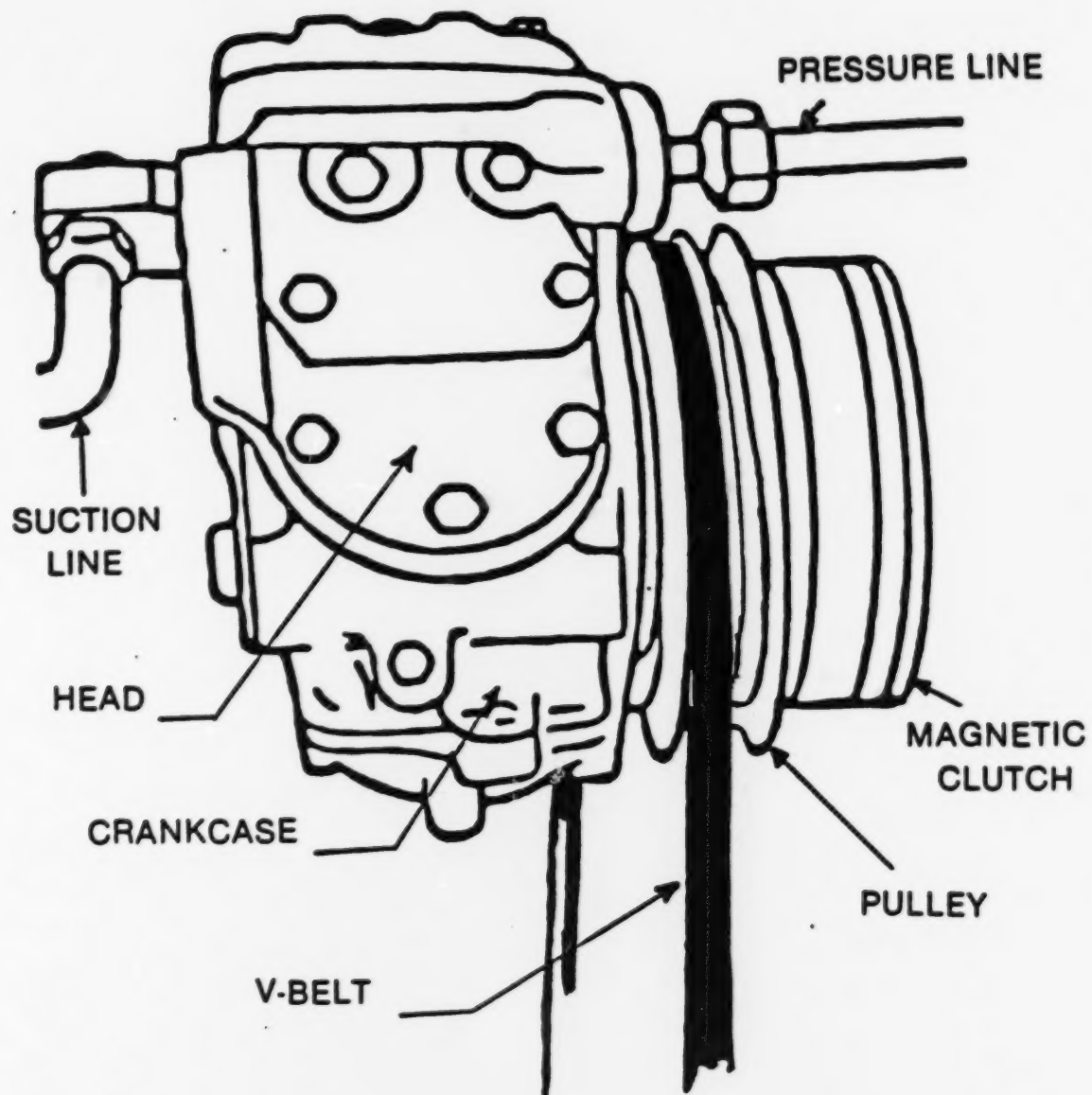
17. Order of operations

18. Adding integers

19. Squaring a number

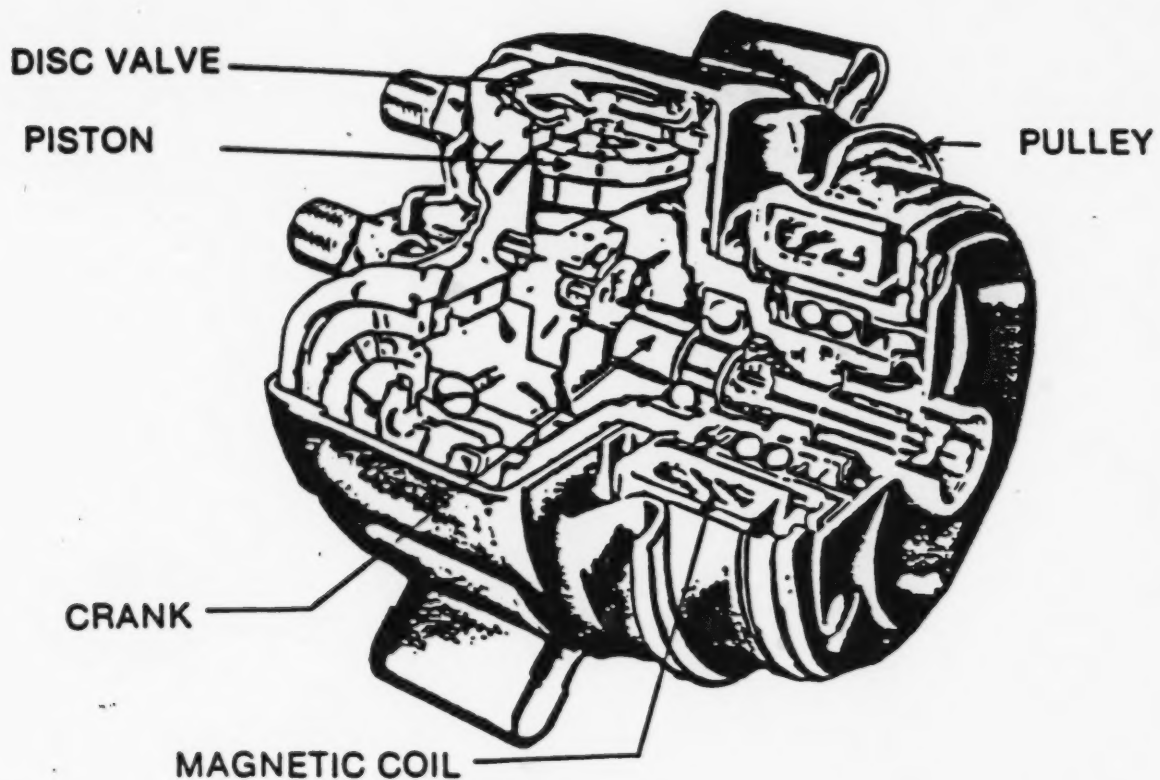
20. Adding decimals

COMPRESSOR



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COMPRESSOR



MECHANICAL ADVANTAGE $Ma = \frac{\text{OUTPUT FORCE}}{\text{INPUT FORCE}}$

IDEAL GAS LAW $\frac{P_1 V_1}{n_1 R T_1} = \frac{P_2 V_2}{n_2 R T_2}$

COMPRESSOR CAPACITY $V = \frac{\pi D^2}{4} \times S \times N \times R$

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Title: Condenser

Category: Process

Description:

The condenser is a refrigerant tube coil mounted in a series of thin cooling fins to provide a maximum amount of heat transfer in a minimum amount of space. The condenser is mounted directly in front of the radiator where it receives the full flow of ram air from the movement of the car going down the road and from the radiator fan.

The purpose of the condenser is to condense or liquify the gaseous refrigerant coming from the compressor. The refrigerant must yield its heat to the external environment. The air passing through the thin metal layers in contact with the internal tubing of the condenser, causes a large amount of heat to escape. As the refrigerant is cooled it changes into a warm, high pressure liquid which leaves the bottom of the condenser and passes onto an expansion valve and evaporator.

Damage to the condenser can occur from particulate matter in the ram air which can dent or rupture the condenser fins when contact occurs at high road speeds. Engine vibrations and rapid changes in temperature also contribute to damage or inefficiencies. Servicing the condenser is easier than some of the other air conditioning components because of its favorable location.

Title: Condenser

Category: Process

Condensers and Science Concepts:

1. TENSILE FORCE - An external force that creates a pulling or stretching action on a material. The "ram air" or external air cooling the condenser exerts a force on the metal parts of the condenser which increases with the speed of the automobile.
2. STRESS - An internal force applied to each square inch of the cross-sectional area of a material. This stress is the result of the tensile force applied to the exposed cross sectional area of the condenser.
3. BRITTLENESS - The inability of a material to deform very much before rupture. The shorter the deformation required for rupture, the more brittle the material. The vibrations of the automobile and the stress on the condenser parts require the use of aluminum in contrast to copper because of the brittleness of the latter.
4. SURFACE AREA - The rate of cooling and consequent condensation of the refrigerant will be dependant on the total surface area allowing heat loss to the ram air blowing through the condenser.
5. CONDENSATION - The change of phase from a vapor to a liquid. The nature of the refrigerant, the volume of the tubing and the temperature of the external environment will determine the rate of phase change.
6. HEAT OF VAPORIZATION - The heat that must be removed to convert a substance from a gas to a liquid. The heat of vaporization in freon - 12, a common automobile refrigerant, is 71.04 BTU/lb. in one atmosphere of pressure.
7. AIR VELOCITY - The effect of air velocity is to increase the condenser's capacity as the air speed is increased. When an air speed of 400 feet per minute is used, a 2.5 BTU per square foot per degree F per hour value will be satisfactory.

Title: Condenser

Category: Process

Condensers and Science Concepts:

8. CAPACITY EFFECTS - If a compressor is under capacity, the compressor head pressure will rise in proportion to dissipate the required amount of head. If the capacity of the condenser is too small, the result will be a decrease in compressor efficiency, an increase in motor load and a decrease in the life of the unit.
9. CONDUCTION - The conduction of heat released during condensation is dependant upon the specific heats of the metals used.
10. SPECIFIC HEAT - The amount of heat which must be added to one gram of a substance to raise the temperature one degree Celsius. The lower the specific heat, the faster the conduction of heat through the material. Aluminum's specific heat is 0.22 cal/g C.
11. BOYLE'S LAW - The pressure is inversely proportional to the variance in volume if the temperature remains constant. In the condenser the vapor and liquid remain under relatively high pressure.
12. CHARLES' LAW - The volume of a substance varies directly with its temperature. As the heat is lost in the condenser the volume taken up by the refrigerant is reduced as liquids take up less space than gases under fairly constant pressure conditions.

Title: Condenser

Category: Process

Math Concepts

1. $S = \frac{F}{A}$

Tensile or compressive stress (lb./in.² or Pa) = $\frac{\text{Force (lb. or Newtons)}}{\text{Cross-Sectional Area (in.² or m²)}}$

2. Surface Area = N x A

N = number of fins

A = area of each fin

3. $Q = m Lv$

Heat change = mass of substance x heat of vaporization constant.

4. $v = \frac{\Delta d}{t}$

Velocity = $\frac{\text{change in distance}}{\text{time}}$

5. $\frac{Q}{\text{hr.}} = KA\Delta T$

heat transferred per hour (Btu/hr.) = heat conductivity x Area x temp. difference

6. $\frac{p_2}{p_1} = \frac{V_1}{V_2} \quad \frac{\text{pressure (2)}}{\text{pressure (1)}} = \frac{\text{Volume (1)}}{\text{Volume (2)}}$

p₁, p₂ are the pressures at conditions one and two in lb./in.² or Pa

V₁, V₂ are the volumes at conditions one and two in in.³ or m³

Note: Pressures are absolute and the temperature is constant.

7. $P \text{ absolute} = P \text{ gage} + 14.7 \text{ lb./in.}^2$

Pressure (absolute) = Pressure (gage) + 14.7 lb./in.²

8. $P \text{ absolute} = P \text{ gage} + 101 \text{ kPa}$

Pressure (absolute) = Pressure (gage) + 101 kPa

9. $\frac{V_1}{V_2} = \frac{T_1}{T_2} \quad \frac{\text{Volume (1)}}{\text{Volume (2)}} = \frac{\text{Temperature (1)}}{\text{Temperature (2)}}$

V₁, V₂ are the volumes at conditions one and two in in.³ or m³

T₁, T₂ are the temperatures at conditions one and two in T_k

Note: The pressure is constant.

10. $T_k = T_c + 273 \quad \text{Temperature (kelvin)} = \text{Temperature (Celsius)} + 273$

T_k represents absolute temperature

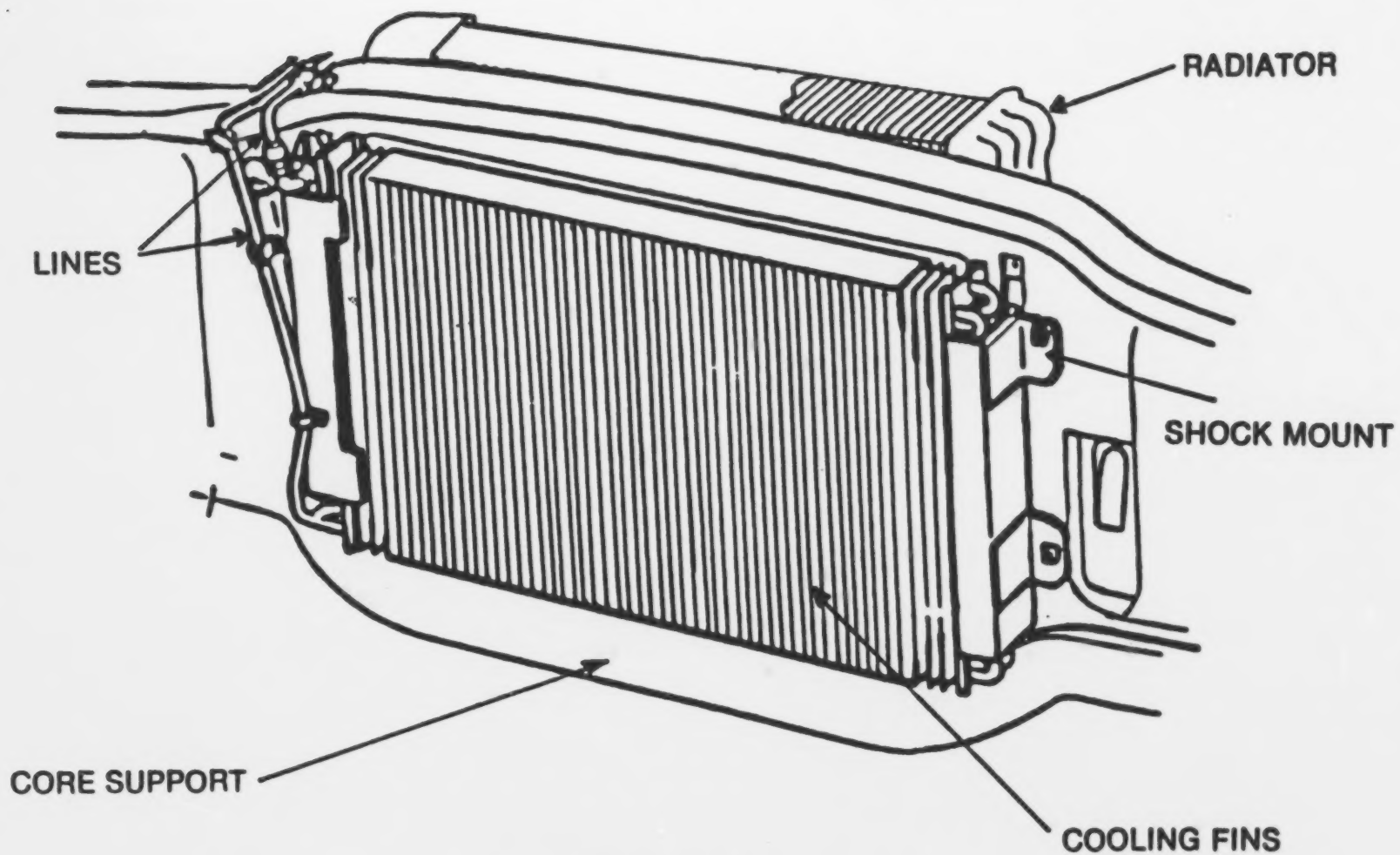
Title: Condenser

Category: Processes

Math Concepts

11. Division of decimals
12. Multiplication of decimals
13. Solving proportions
14. Adding integers

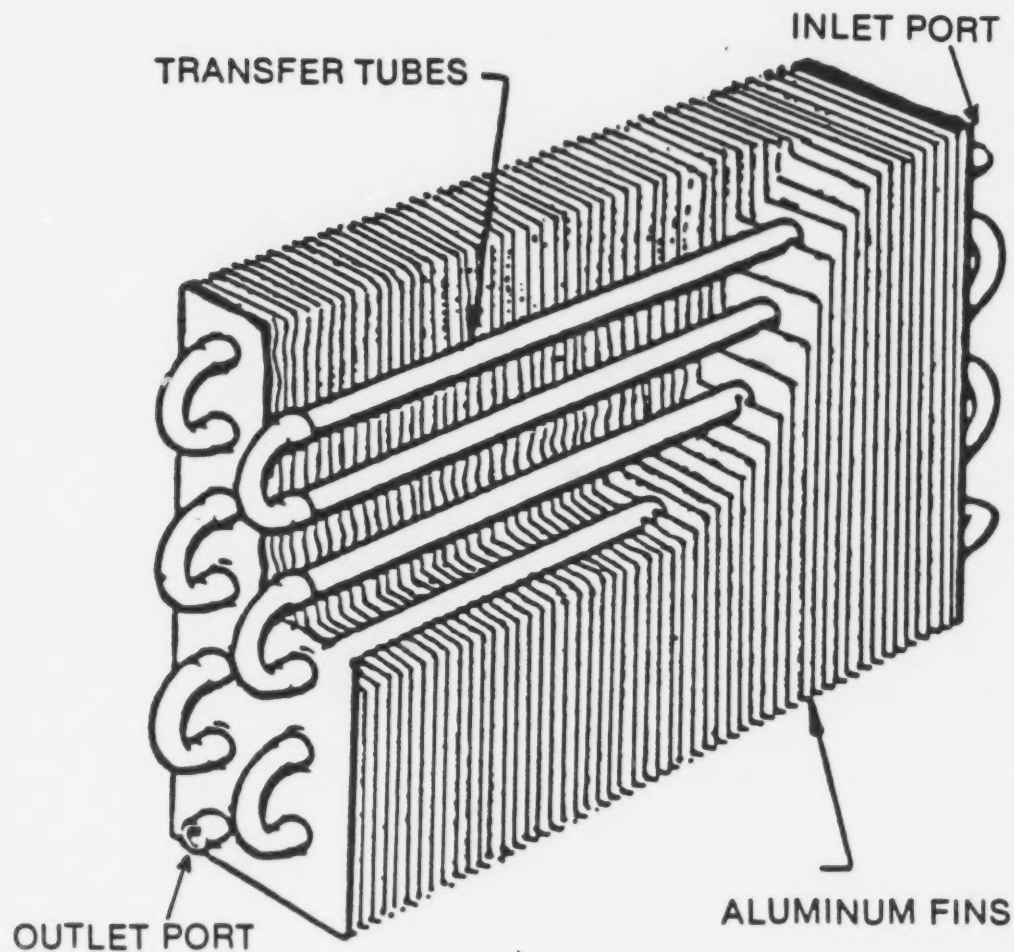
CONDENSER



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CONDENSER

SECTIONAL VIEW



STRESS

$$S = \frac{F}{A}$$

HEAT ABSORPTION

$$Q = m L_v$$

AIR VELOCITY

$$v = \frac{\Delta d}{t}$$

Title: Evaporator

Category: Process

Description:

The evaporator is the structure that cools and dehumidifies the air before it enters the passenger compartments of the car. The high-pressure liquid refrigerant from the condenser flows through the flow - control mechanism into the low pressure area of the evaporator. The refrigerant begins boiling immediately as it is absorbing heat from the evaporator. The air passing over the evaporator loses its heat to the cooler coil, and the air is also dehumidified. The moisture condensed by the evaporator coil is drained off onto the roadway.

Factors which are important in the design of an evaporator include the size and length of the tubing, the number of fins and the amount of air passing past the fins. The heat load; the amount of heat to be removed, is also an important consideration. The evaporator may have several rows of tubing which can be arranged in a number of different configurations to meet heat removal, as well as design requirements.

Servicing is different because of the location of the evaporator. Custom air - conditioner units are available for most years and models of automobiles. Each type of unit requires a different installation procedure. The installation or servicing of some units requires that parts of the fresh air or heater system ducts be removed whereas in other systems, the radio, lighter and even the glove box have to be moved.

Title: Evaporator

Category: Process

Evaporator - Science Concepts:

1. Relative humidity: Cool air leaving the evaporator is at 100% relative humidity. This saturated air, as it mixes air in the conditioned space warms up somewhat. At this point relative humidity is brought down to a comfortable level.
2. Evaporation: The low pressure liquid refrigerant changes into a relatively low pressure vapor after heat is absorbed through the evaporator from the cooled air compartment.
3. Condensation; Water vapor in the air to be cooled changes into a liquid and is drained out the bottom of the evaporator.
4. Dry bulb temperature: In air conditioning, the air temperature indicated is usually a dry bulb temperature (db) taken with the sensitive element of the thermometer in the dry condition.
5. Wet bulb temperature: When a wick which is wet surrounds the thermometer bulb, the rate of evaporation lowers the temperature reading from the dry bulb level. The resultant reading is called a wet bulb temperature. This temperature is used to determine the relative humidity of the conditioned air.
6. Surface Area: The surface area of the evaporator is needed to calculate the heat transfer which will take place between the cooled compartment and the air conditioning system.
7. Air Flow: The deeper the evaporator, the greater the fin spacing to minimize air restriction. Evaporators which have 6 to 8 inch depth usually have one - inch spacing whereas those with an 18 or 20 in. depth have a 1½ inch spacing.

Title: Evaporator

Category: Process

Evaporator - Science Concepts:

8. Tube Diameters: The tubing used in the condenser is usually 5/8 in. outside diameter (OD).
9. Heat Load: The total heat load consists of the amount of heat to be removed from the automobile interior during a certain period. The evaporator capacity must be matched to the compressor's running time since both must be in operation at the same time.
10. Heat Leakage: Heat leakage is a variable to be considered in determining the heat load. Heat leakage is determined by; amount of exposed surface; thickness and kind of insulation and temperature differences inside and outside of the automobile.
11. Heat Transfer and Temperatures Difference: The difference in temperature between the external environment and the auto interior varies directly with the amount of heat leaking into the auto. This heat contributes to the heat load to be removed at the evaporator.
12. Insulation: The thicker the insulation, the less heat will flow through it. This relationship is linear in that twice as much heat will leak through a one inch wall as though a two inch wall of polystyrene.
13. Charles' Law: The evaporator absorbs heat and consequently the volume occupied by liquids and gases in the system will change.
14. Boyle's Law: Changes in liquid and gaseous volumes result in variations of pressure within the evaporator.

Title: Evaporator

Category: Process

Math Concepts:

7. $\frac{p_1}{p_2} = \frac{V_1}{V_2}$ $\frac{\text{pressure (2)}}{\text{pressure (1)}} = \frac{\text{Volume (1)}}{\text{Volume (2)}}$

p_1, p_2 are the pressures at conditions one and two in lb/in^2 or Pa

V_1, V_2 are the volumes at conditions one and two in IN^3 or M^3

Note: Pressures are absolute and temperature is constant

8. $P \text{ absolute} = P \text{ gage} + 14.7 \text{ lb./in.}^2$

$\text{Pressure (absolute)} = \text{Pressure (gage)} + 14.7 \text{ lb./in.}^2$

9. $P \text{ absolute} = P \text{ gage} + 101 \text{ K Pa}$

$\text{Pressure (absolute)} = \text{Pressure (gage)} + 101 \text{ K Pa}$

10. $\frac{V_1}{V_2} = \frac{T_1}{T_2}$ $\frac{\text{Volume (1)}}{\text{Volume (2)}} = \frac{\text{Temperature (1)}}{\text{Temperature (2)}}$

V_1, V_2 , are the volumes at conditions one and two in IN^3 or M^3

T_1, T_2 are the temperatures at conditions one and two in Tk

Note: The pressure is constant

11. $T_k = T_c + 273$ $\text{Temperature (Kelvin)} = \text{Temperature (Celsius)} + 273$

T_k represents absolute temperature

12. Division of decimals

13. Multiplication of decimals

14. Converting a ratio to a percent

15. Solving proportions

16. Adding integers

17. Squaring a number

18. Adding decimals

Title: Evaporator

Category: Process

Math Concepts:

1. Relative humidity (rh) = $\frac{\text{amount of moisture in sample air}}{\text{total amount of moisture which the air can absorb}} \times 100$
(at stated temperature & pressure)

2. Total heat load = heat leakage + heat usage.

3. Heat usage = load per cu. ft. x volume.

4. Heat Leakage

$$K_T = \frac{K_1}{\text{Thickness}}$$

K_T = total thermal conductance

K_T = conductance for a 1 in. thickness

$$R_T = R_1 + R_2$$

R_T = total resistance to heat flow

R_1 = resistance of substance 1

R_2 = resistance of substance 2

$$\frac{1}{K_T} = \frac{1}{K_1} + \frac{1}{K_2}$$

$$(R = \frac{1}{K})$$

5. $\frac{Q}{\text{hr.}} = K A \Delta T$

heat transferred per hour (Btu /hr.) = heat conductivity x Area x temp. difference

6. Evaporator area = total fin area + area + actual tube area + tube bend area

* Formulas used for fin area

Area = length x width

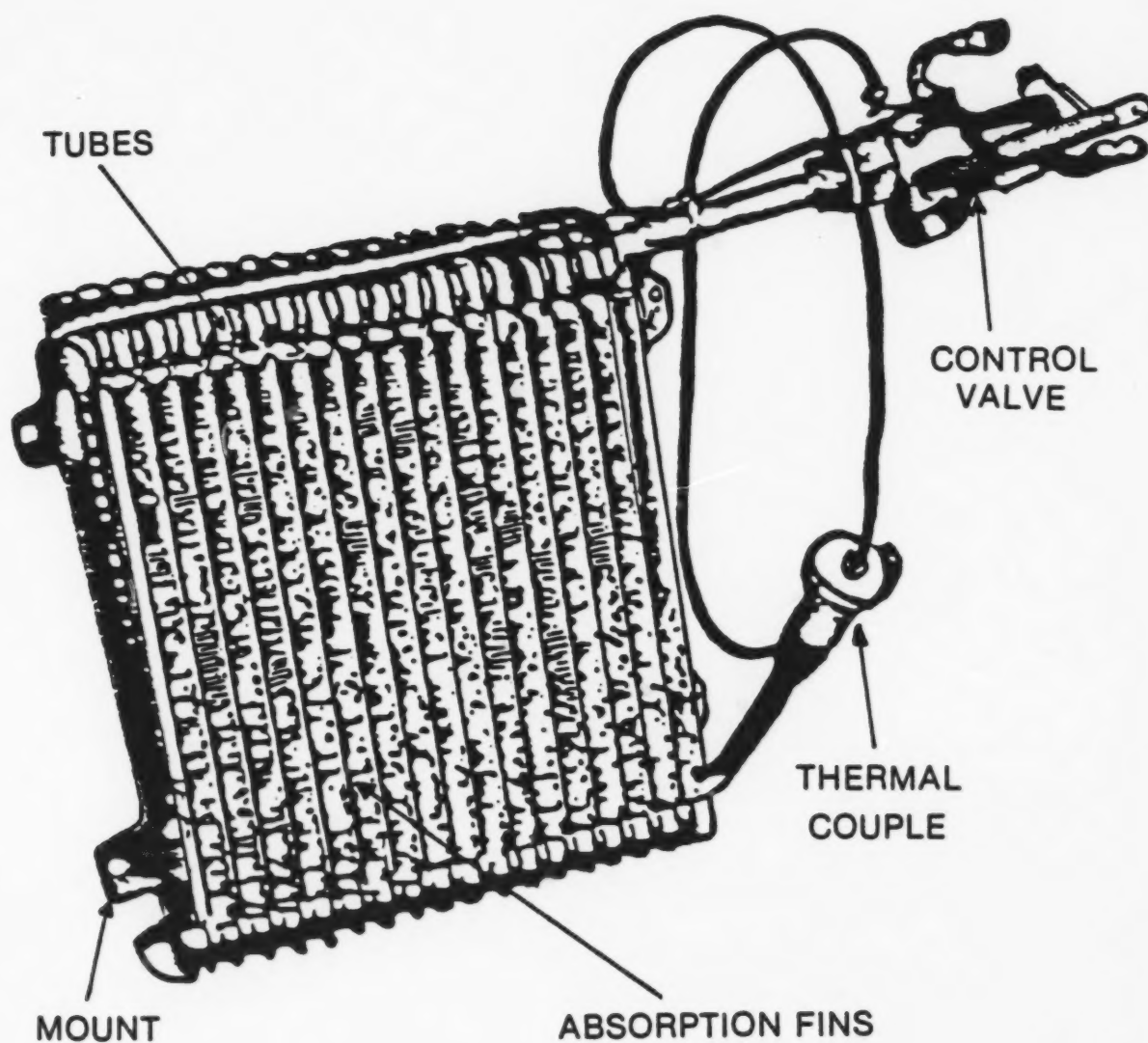
$$\text{Area} = \frac{\pi \times \text{Diameter}^2}{4}$$

* Area of tube = length of tube x circumference of tube

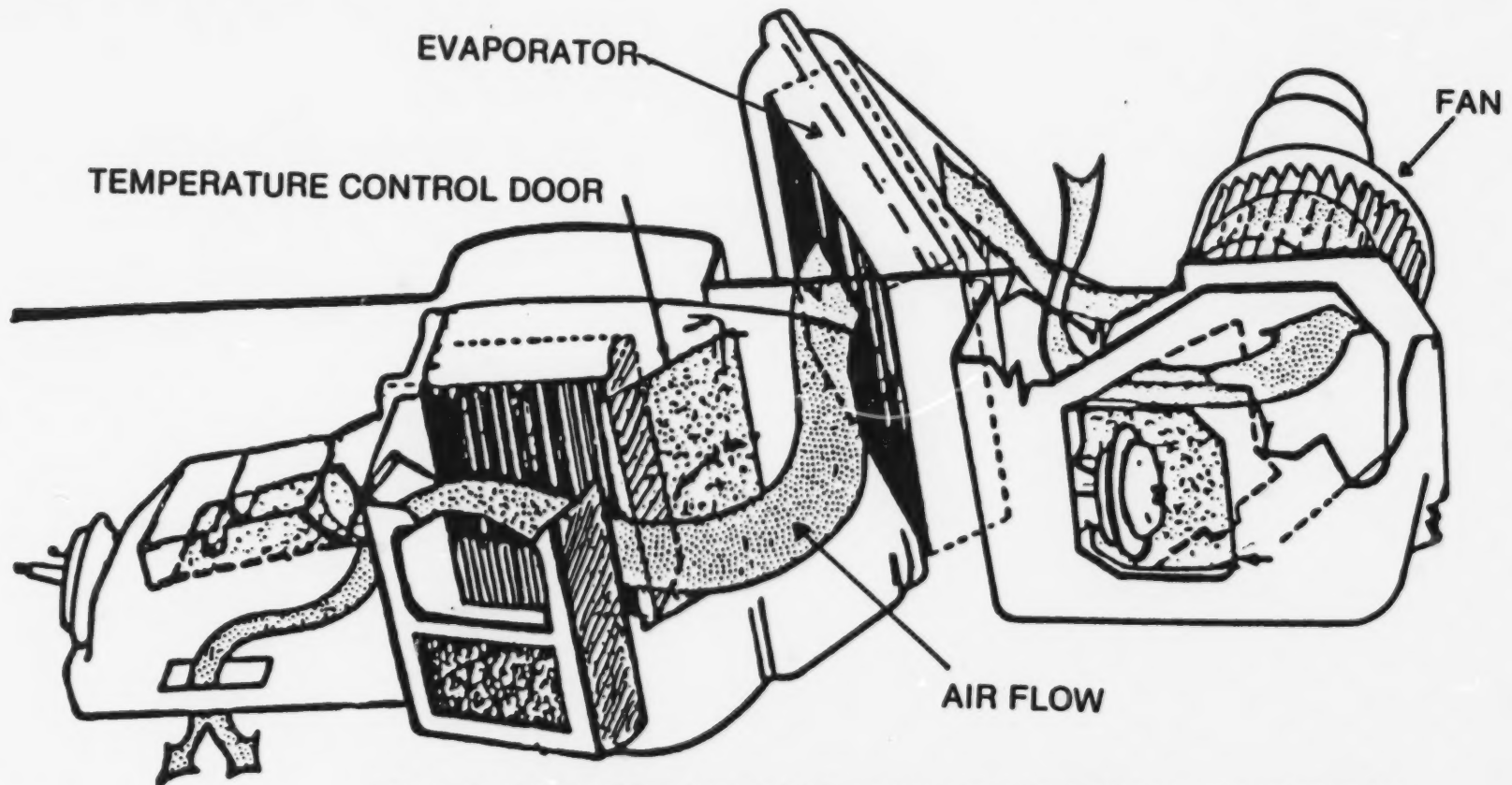
$$\text{Circumference} = \pi \times \text{Diameter}$$

* Tube bend area = length of bend x circumference x no. of bends

EVAPORATOR

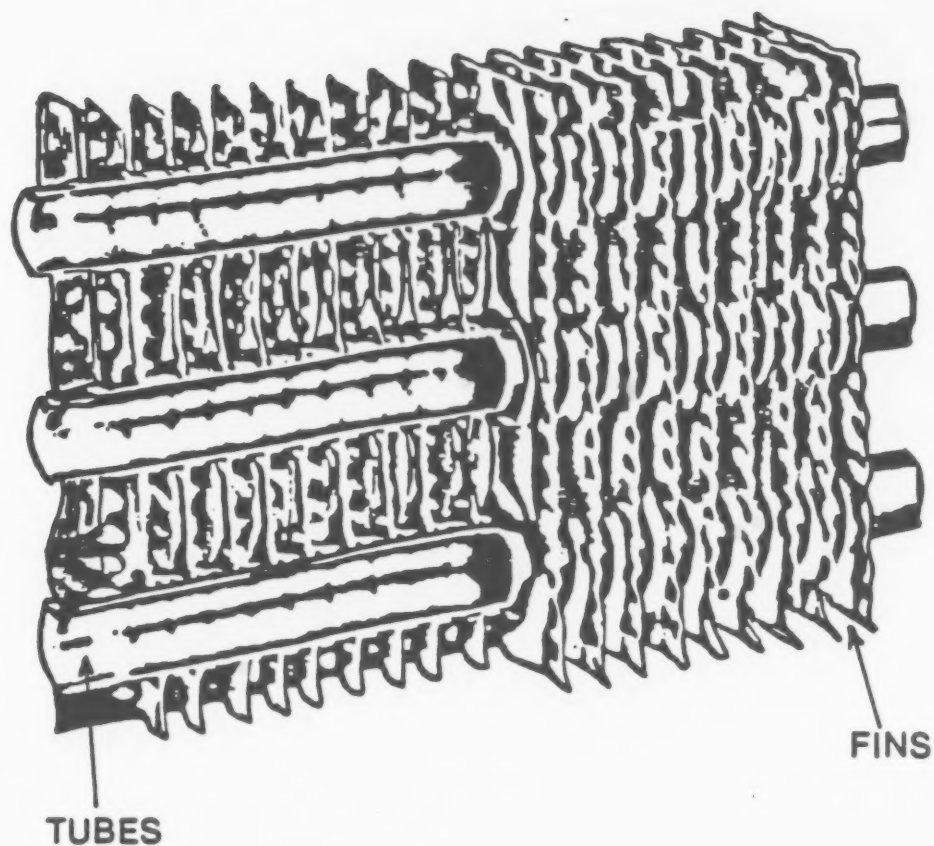


EVAPORATOR LOCATION



THE EVAPORATOR IS LOCATED IN THE FIREWALL OF THE CAR,
UNDER THE DASH AND IN CONJUNCTION WITH THE HEATER
SYSTEM OF THE CAR.

EVAPORATOR CUTAWAY



THERMAL RESISTANCE

$$R_T = R_1 + R_2$$

THERMAL CONDUCTANCE

$$K_T = \frac{K_1}{\text{THICKNESS}}$$

HEAT RATE

$$\frac{Q}{hr} = KA\Delta T$$

Title: Basic Electrical Circuits

Area of Study: System

Description:

How is electricity transmitted through circuits? The different circuits are illustrated on this transparency, the series circuit and the parallel circuit. Terms, definitions and formulas included will enable students to become familiar with the language of electricity and apply appropriate skills where and when necessary.

Science Concepts:

1. Circuit - the pathway through which an electric current travels along a conductor. As the electrons are recirculated a complete circuit is created.
2. Series Circuit - there is only one path for the electrons to flow through. The elements are connected end to end in series. If one element burns out everything in the circuit goes out.
3. Parallel Circuits - are circuits that have more than one path for electrons to flow through. They are really several completely separate circuits that receive their power from the same source. One device or element can burn out without affecting the other devices.
4. Conductor - a material in which electricity can flow easily. Flowing electrons are attracted from the outside orbit of most metal atoms, and a few other materials that can carry electricity. The conductivity of a material depends upon the degree of attraction between the positive nucleus of an atom and the electrons in the outer orbit. Good conductors of electricity are those materials in which there is less attraction between the positive charge of the nucleus and the free flow of electrons in the outer orbit. Good conductors of electricity are copper, silver, iron and many other metals.
5. Current - electrons in motion. It is the movement of free electrons as they are attracted to positively charged atoms. The movement is started by a change in pressure, the characteristics of the material itself or a change in temperature.
6. Resistance - friction in an electrical circuit. The amount of opposing force to the movement of electrons through a material is called resistance. Resistance is present in varying degrees in different materials. Those

materials which are good conductors of electricity have a minimum of resistance to current. In contrast, those which oppose the flow of electrons have a high resistance and are good insulators.

7. Ampere - the rate of flow of an electrical current. The coulomb is the unit of measurement for an electric charge. It takes 6.25×10^{18} electrons for a single coulomb of charge.

As the electrons move through a material the rate is expressed in amperes. An ampere describes the amount of electrical charge and the time.

one ampere = one coulomb each second
1 amp = 6.25×10^{18} electrons/second

8. Voltage - the electromotive force that causes the movement of electrons in a circuit. Voltage is the energy it takes to push the electrons through the electrical circuit. It is created by piling more electrons on one end of a wire than there are on the other end. The electrical potential energy of a coulomb of electrons is measured by a unit called the volt. Electrical charges do not move until there is a difference between the potential energy of one charge and the potential energy of another charge. This difference in energy is expressed in volts. It is the comparison of the electromotive forces between two unequal charges.

9. Watt - the common unit of power in electrical systems. One watt is representative of the power used when one ampere of current is pushed through a circuit with one volt of pressure. Watts = volts x amperes.

10. Ohm's Law - the relationship of voltage, resistance and current. Ohm's law states: current is equal to the voltage divided by the resistance.

$$\text{current} = \frac{\text{voltage}}{\text{resistance}} \text{ or } I = \frac{E}{R}$$

When any two of the variables are known the unknown can be substituted and determined;

$$R = \frac{E}{I} \quad E = IR \quad \text{or} \quad I = \frac{E}{R}$$

TITLE: Basic Electrical Circuits

DESCRIPTIONS:

How is electricity transmitted through circuits? The different circuits are illustrated on this transparency, the series circuit and the parallel circuit. Terms, definitions, and formulas included will enable students to become familiar with the language of electricity and apply appropriate skills where and when necessary.

MATH CONCEPTS:

1. The current in any circuit equals the voltage divided by the resistance. If the voltage is 100 volts, and the resistance is 20 ohms, the current can be found by using the formula:

$$I = \frac{E}{R}$$

$$I = \frac{100 \text{ volts}}{20 \text{ ohms}}$$

$$I = 5 \text{ ohms}$$

A relationship between current, voltage, and resistance can be also written as:

$$E = I \times R \text{ and } R = \frac{E}{I}$$

2. The watt is the unit of measure for electrical power. It is equal to the voltage times the current. Where power is represented by P, voltage by E and current by I, the formula becomes:

$$P = E \times I$$

The power will change when either the voltage or current changes.

e.i. voltage across a resistor is 100 volts.
Current through the resistor is 5 amperes. Power is equal to voltage times current.

$$P = E \times I$$

$$P = 100 \times 5$$

$$P = 500 \text{ watts}$$

3. The resistance of the bulb can be found by the following formula: R stands for resistance, P stands for power and E stands for voltage.

$$P = \frac{E^2}{R}$$

$$100 = \frac{120 \times 120}{R}$$

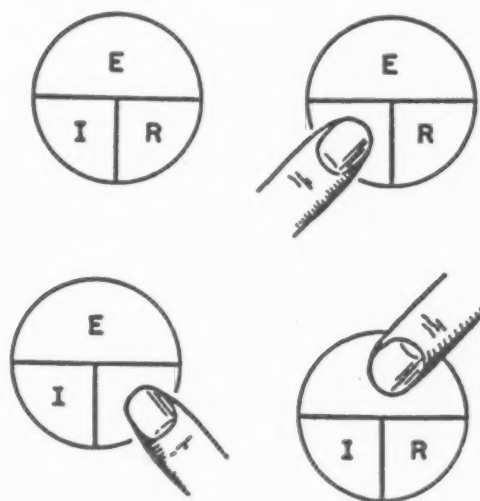
$$100 = \frac{14400}{R}$$

$$R = \frac{14400}{100}$$

$$R = 144 \text{ ohms}$$

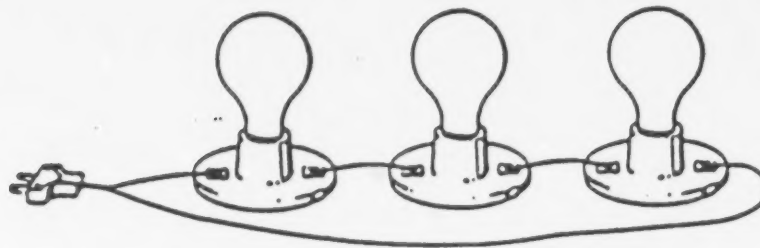
OHMS LAW

There are three quantities in this formula. When any two of the quantities are known the power can be determined.



Place your finger on the unknown value. The remaining two letters will give the formula to use for finding the unknown value. In figure IV for example, $E = I \times R$

BASIC ELECTRICAL CIRCUITS

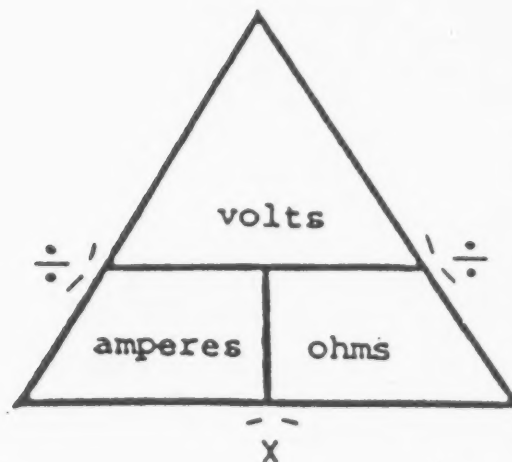


SERIES CIRCUIT

Ohm's Law

$$I = \frac{E}{R}$$

Amperes



$$R = \frac{E}{I}$$

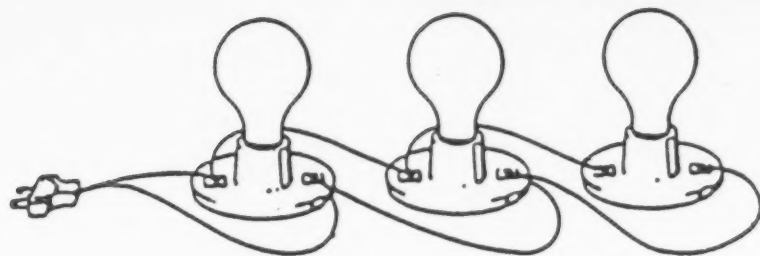
Resistance

$$E = IR$$

Volts

WATTS = VOLTAGE X AMPERES

BASIC ELECTRICAL CIRCUITS



PARALLEL CIRCUIT

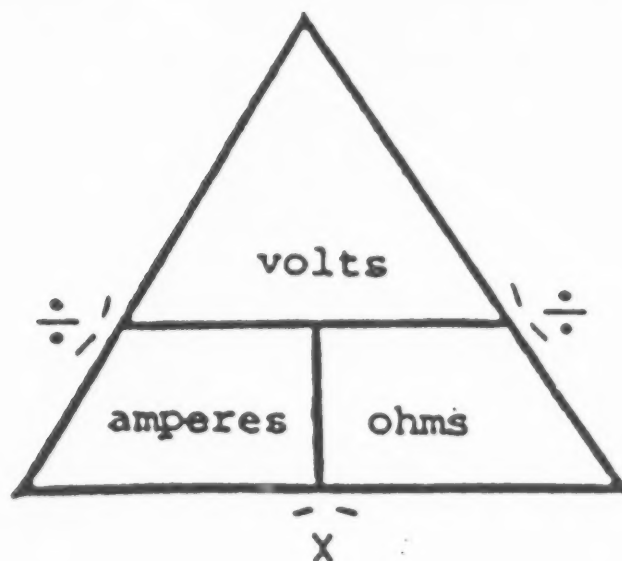
Ohm's Law

$$R = \frac{E}{I}$$

Resistance

$$I = \frac{E}{R}$$

Amperes



$$E = IR$$

Volts

WATTS = VOLTAGE X AMPERES

TITLE: BATTERY

CATEGORY: INNOVATION

DESCRIPTION:

In a battery, electrical energy is produced by chemical reaction between the active materials of the dissimilar plates and the sulfuric acid of the electrolyte. The availability and amount of electrical energy which can be produced in this manner is limited by the active area and weight of the materials in the plates and by the quantity of sulfuric acid in the electrolyte. After most of the available active materials have reacted, the battery can produce little or no additional energy. The battery then is said to be DISCHARGED. Before the battery can be further discharged, it must be recharged by being supplied with a flow of direct current from some external source. The charging current must flow through the battery in a direction OPPOSITE to the current flow during discharge. Therefore, the positive terminal of the charging unit should be connected to the positive terminal of the battery. This causes a reversal of the discharge reactions and the battery becomes recharged.

SCIENCE CONCEPTS:

1. Matter is made of atoms.
2. Atoms have positive nuclei.
3. Negative electrons orbit the atomic nuclei at different energy levels.
4. The outermost level of electrons determine the reactivity of an atom.
5. Ionic bonds form between atoms when outer electrons are gained by one atom and lost from another atom.
6. Covalent bonds form between atoms when outer electrons are shared between two atoms.
7. Elements may be oxidized during a chemical reaction. Oxidization involves loss of electrons from the outer level.
8. Elements may be reduced during a chemical reaction. Reduction involves gain of electrons.
9. Chemical reactions proceed in both directions until an equilibrium is reached.
10. Changing the concentration on either side of a reaction changes the point of equilibrium. (Removing electrons from the negative side of a battery causes the discharge reactions to proceed. Adding electrons to the negative side of a battery reverses these reactions and recharges the battery.)
11. Direct Current (D.C.) may be produced by linked oxidation-reduction reactions.
12. Batteries convert stored chemical energy into electrical energy.

TITLE: BATTERY

CATEGORY: INNOVATION

MATHEMATICAL CONCEPTS:

1. One must often use integers (positive and negative numbers) in understanding chemical reactions.
2. Reinforce adding and subtracting decimals.
3. Ratio applies to a variety of situations.
4. Students use the Axioms of Equality.

Adding integers--

Let $a = 4$, $b = -2$, $c = 2$, $d = 6$

$$a + b = c$$

$$b + d = a$$

$$a + c = d$$

Subtracting integers--

$$a - b = d$$

$$c - a = b$$

$$a - d = b$$

$$c - b = a$$

Axioms of Equality--

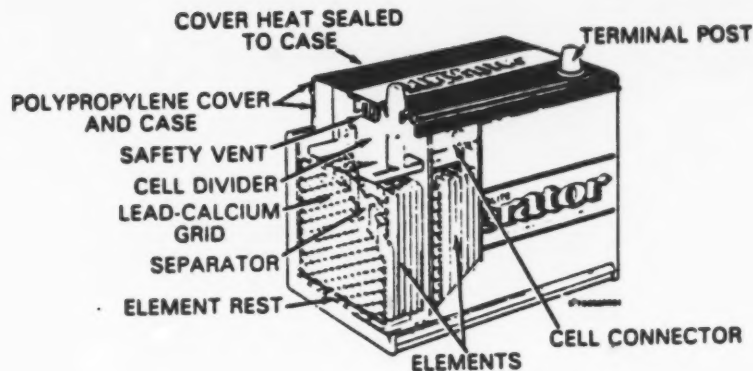
For all real numbers-- a , b , and c :

Reflexive Property $a = a$

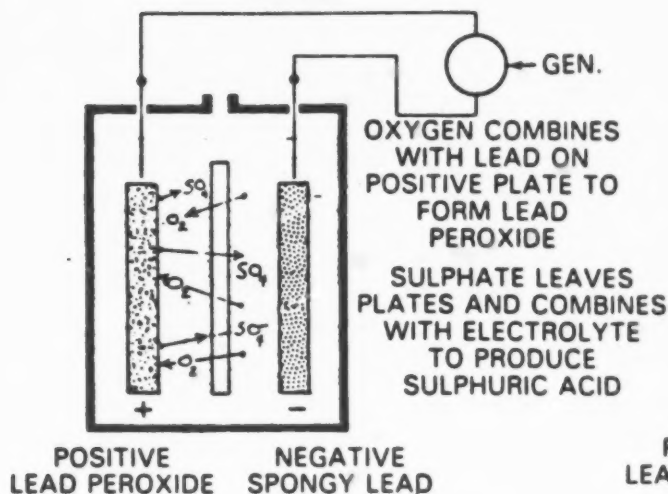
Symmetric Property if $a = b$, then $b = a$

Transitive Property if $a = b$, and $b = c$, then $a = c$

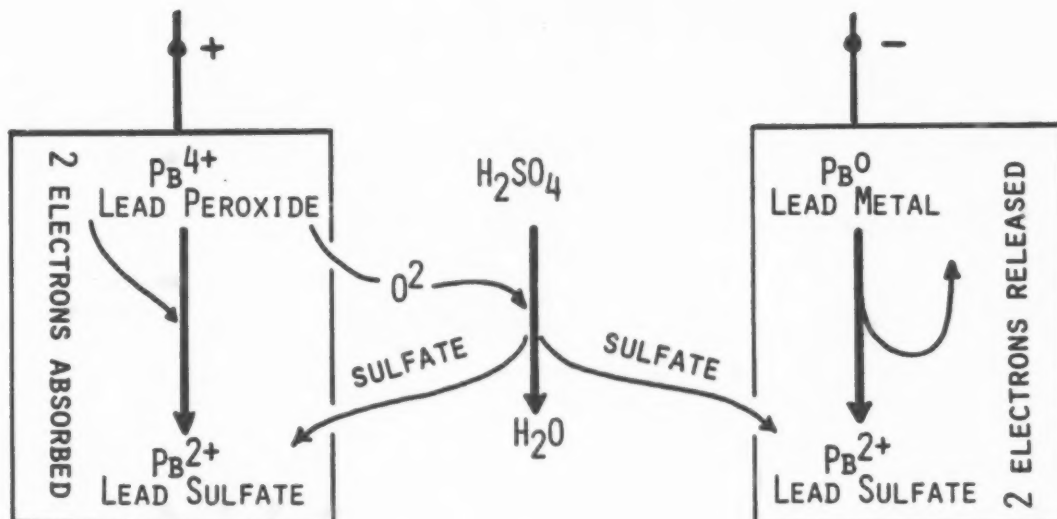
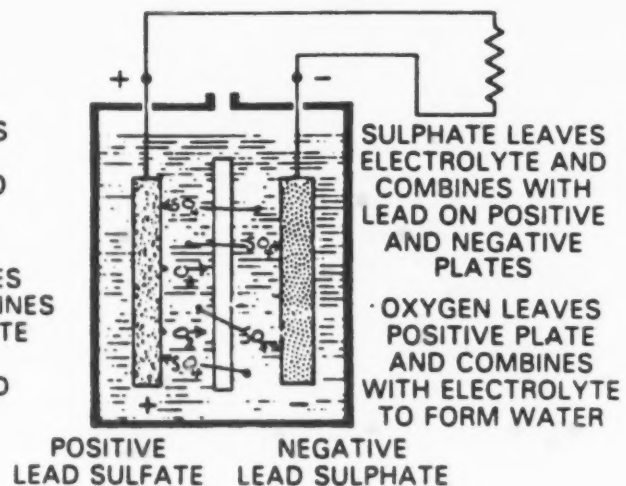
BATTERY



CHARGE



DISCHARGE



TITLE: BIMETAL DEVICES

CATEGORY: INNOVATION

DESCRIPTION:

Bimetal devices are made of two attached dissimilar metals. They operate on the principle of differential expansion of two metals exposed to a temperature change. These devices are usually composed of two metals which expand at greatly different rates.

Bimetals are incorporated in a variety of different controls and indicators such as thermometers, thermostats, electric flashers, and circuit breakers. Because they are dependable, durable, and economical, they are still in common use today.

SCIENCE CONCEPTS:

1. The energy associated with the random motion of atoms in a substance is thermal or heat energy.
2. Most solids expand when heated and contract when cooled.
3. Heating increases molecular speed and molecules travel farther apart.
4. As current flows, the charge carriers (electrons) collide with the free electrons of the conductor. These collisions produce heat.
5. The heating of a conductor is proportional to the power dissipated as current flows.
6. The degree of thermal expansion of a substance depends on the nature of the material.

TITLE: BIMETAL DEVICES

CATEGORY: INNOVATION

MATHEMATICAL CONCEPTS:

1. Thermal coefficient of linear expansion is the change in length of an object, per unit length for each degree of temperature change.

Table of Thermal Coefficients for Different Materials

Material	Thermal Coefficient per °C
Aluminum Alloy (Average)	0.000023
Brass	0.000020
Bronze	0.000018
Concrete	0.000014
Copper	0.000016
Glass, plate	0.000009
Steel (average)	0.000012

2. $C = \frac{5}{9} (F - 32)$

C = degrees Celsius

F = degrees Fahrenheit

3. $\Delta L = \alpha \cdot L \cdot \Delta T$

ΔL = change in length

α = thermal coefficient of linear expansion

L = original length

ΔT = temperature change in degrees Celsius

4. $P = I^2 \cdot R$

P = power in watts

I = current in amps

R = resistance in ohms

5. $P = I \times V$

P = power

I = current

V = voltage

6. $P = \frac{V^2}{R}$

P = power

V = voltage

R = resistance

7. $y = \frac{3(\alpha_1 - \alpha_2)(T_2 - T_1)l^2}{4d}$

y = amount of deflection of bimetal strip

α_1 = linear expansion coefficient of metal 1

α_2 = linear expansion coefficient of metal 2

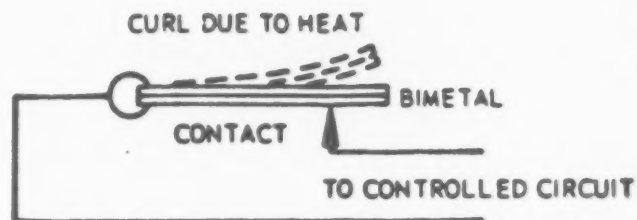
T_1 = lower temperature

T_2 = higher temperature

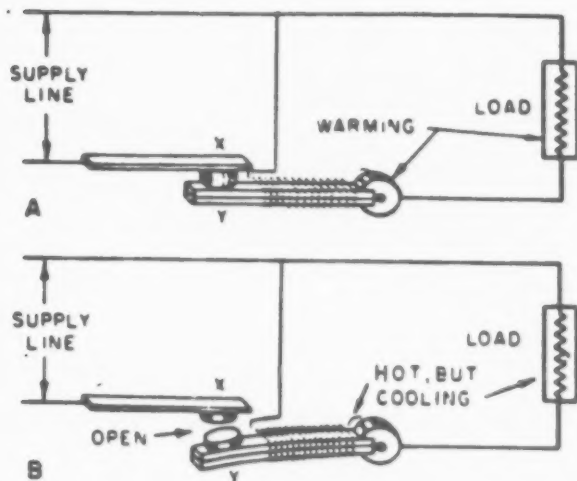
l = length of strip

d = thickness of strip

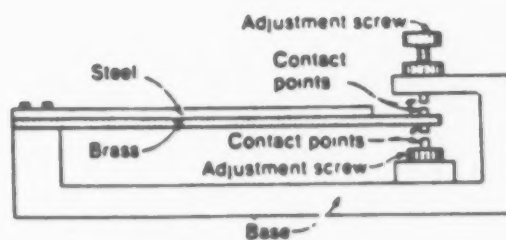
BIMETAL DEVICES



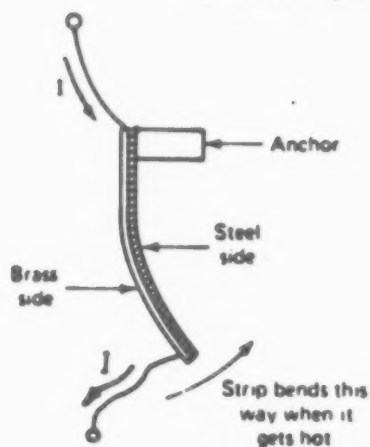
The bimetal curls up (dotted lines) when there is an increase in temperature.



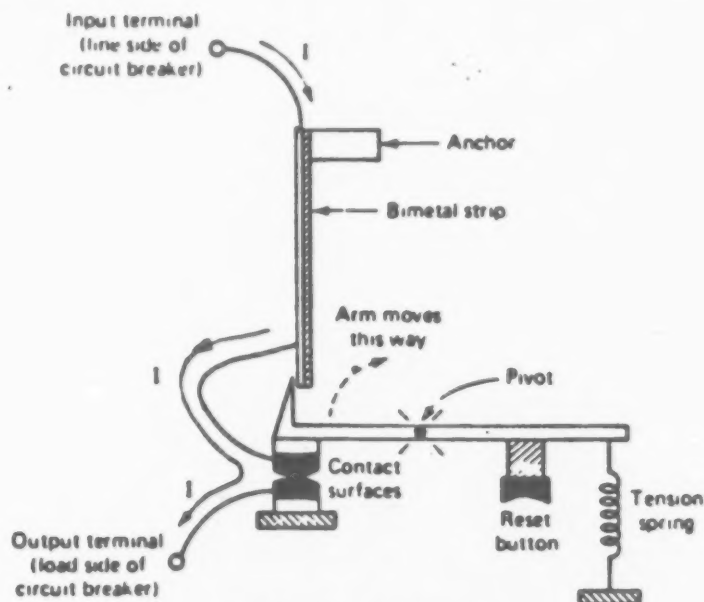
**A Bimetal Thermostat
(ELECTRIC HEATED)**



Construction of a Thermostat



CURRENT HEATED BIMETAL



CIRCUIT BREAKER

TITLE: CARBURETOR

CATEGORY: INNOVATION

DESCRIPTION:

The carburetor vaporizes gasoline and mixes it with air to obtain maximum power from the engine. It enables proper fuel mixture at all speeds.

The downward stroke of the piston draws air into the carburetor above the venturi. The venturi speeds the air on its way to the manifold and a low pressure zone develops just above the discharge tube. This creates a suction of gas out of the discharge tube. The gas is vaporized, mixed with air and forced into the pistons. Optimum power is achieved when the gasoline air mixture is 1 to 15 (1 part gas, 15 parts air.)

SCIENCE CONCEPTS:

1. Bernoulli Principle--A gas moves from a higher pressure zone (reservoir) to a lower pressure zone (venturi). This creates a suction of gas out of the discharge tube.

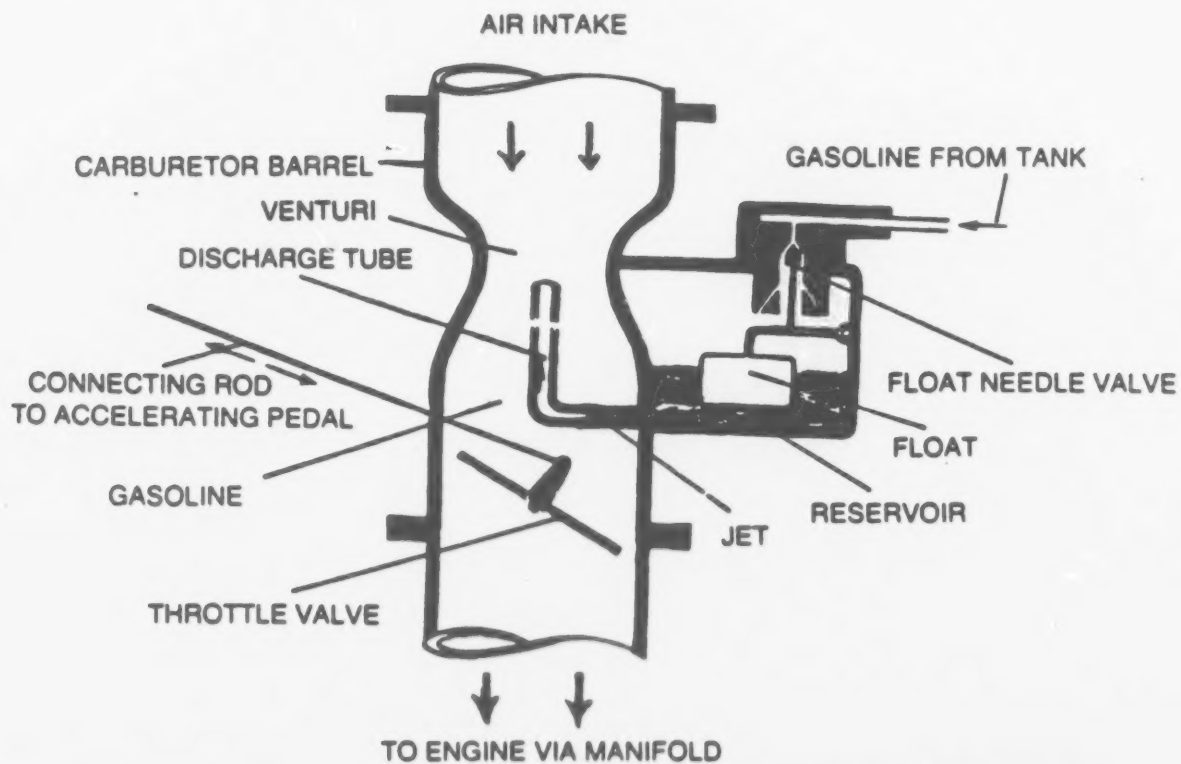
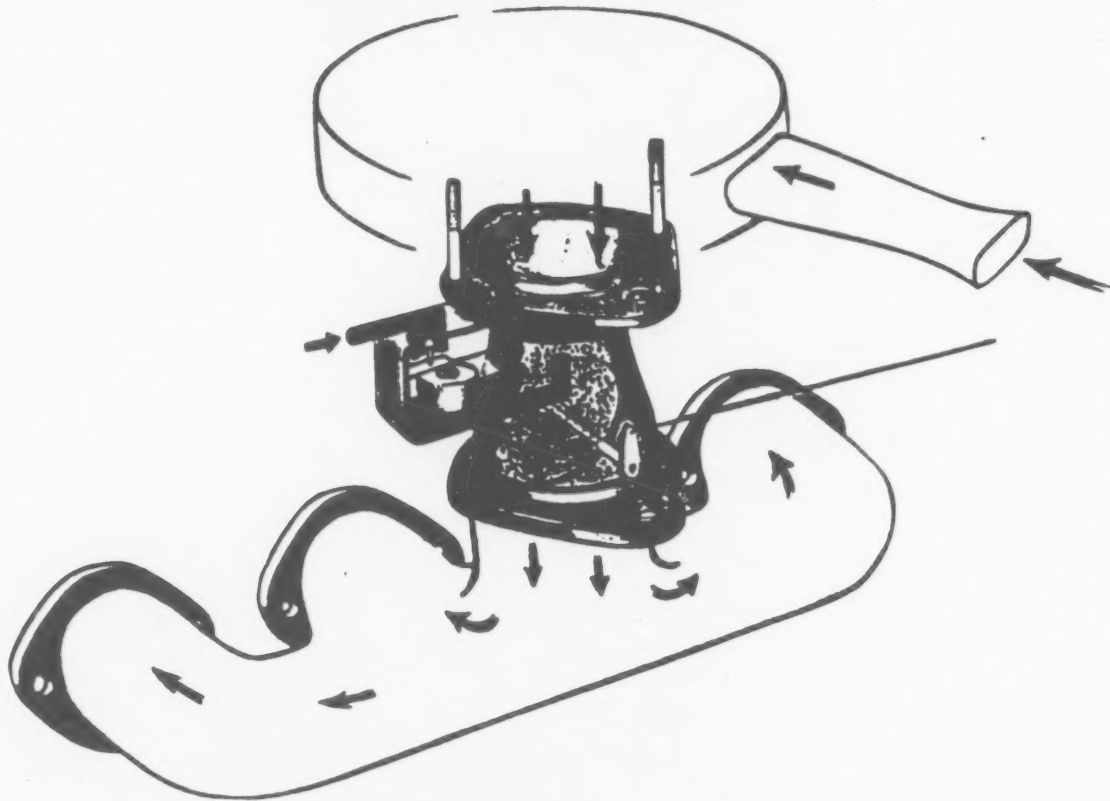
MATHEMATICAL CONCEPTS:

1. Ratio 1:15--what does the one represent? What does the fifteen represent?
2. If you have two liters of gas in the tank, how much air will be needed to satisfy the 1:15 ratio?

$$\frac{1}{15} \frac{\text{Gas}}{\text{Air}} = \frac{\text{Gas (2)}}{\text{Air X}}$$

$$\frac{1}{15} = \frac{2}{X} \quad X = 30$$

CARBURETOR



TITLE: CAPACITORS

CATEGORY: INNOVATION

DESCRIPTION:

Capacitors are the second most common electrical component, second only to resistors. They are made of two metal plates separated by an insulator called a dielectric. The two metal plates have the ability to store or give up electrons depending on the applied outside electrical charge. Their popularity is due to three abilities that they possess:

1. They can store a charge on their plates, thereby acting as a temporary voltage source.
2. They will allow a charge to move between the two plates. This enables the capacitor to slow down electrical events.
3. They are frequency sensitive in A.C. (alternating current) circuits. They can discriminate between A.C. signals of different frequencies.

SCIENCE CONCEPTS:

1. A capacitor stores energy in the form of an electric field.
2. Electric fields are produced by charges and vary in magnitude.
3. Charging a capacitor is work which is conserved and stored as electric potential energy.
4. For any capacitor, the potential difference between plates is proportional to the charge on the plates.
5. Dielectrics vary in effectiveness to diminish an electric field and therefore change capacitance.
6. Capacitance is determined by the:
 1. Area of plates used
 2. Distance between plates
 3. Dielectric between plates
7. Charging a capacitor becomes more difficult as the charge on the plates increases.

TITLE: CAPACITORS

CATEGORY: INNOVATION

MATHEMATICAL CONCEPTS:

1. A capacitance of 1 farad will store a charge of 1 coulomb when 1 volt is placed across it.

1 coulomb = 6.28×10^{18} electrons

1 farad = 1 coulomb per volt

1 microfarad = 10^{-6} farads; 1 picofarad = 10^{-12} farads

2. $E = \frac{1}{2} CV^2$

E = energy stored in capacitor

C = capacitance in farads

V = amount of force in volts

3. $C = Q/V$

C = capacitance in farads

Q = quantity of charge in coulombs

V = amount of force in volts

4. $K \epsilon_0 A/D = C$

K = dielectric constant between plates

ϵ_0 = dielectric free space of a vacuum

$\epsilon_0 = 8.85 \times 10^{-12}$ farads/meter

A = area of plates

D = distance between plates

5. $T = RC$

T = time (in seconds) it takes capacitor voltage to rise to 63% of its maximum

R = resistance in ohms

C = capacitance in farads

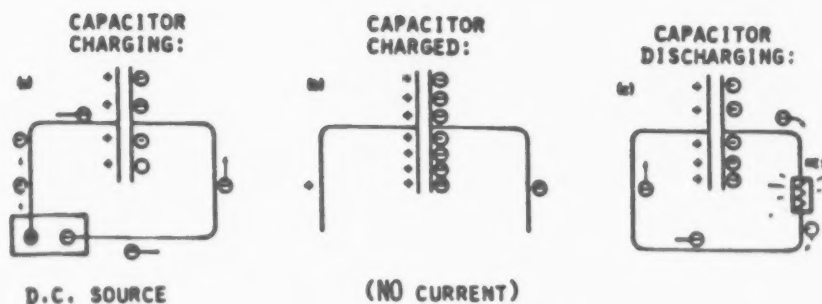
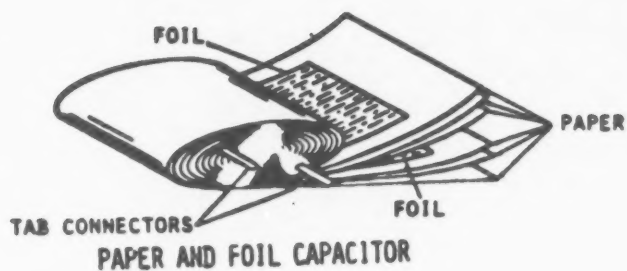
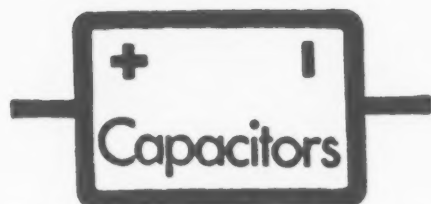
6. $V = IR$

V = amount of force in volts

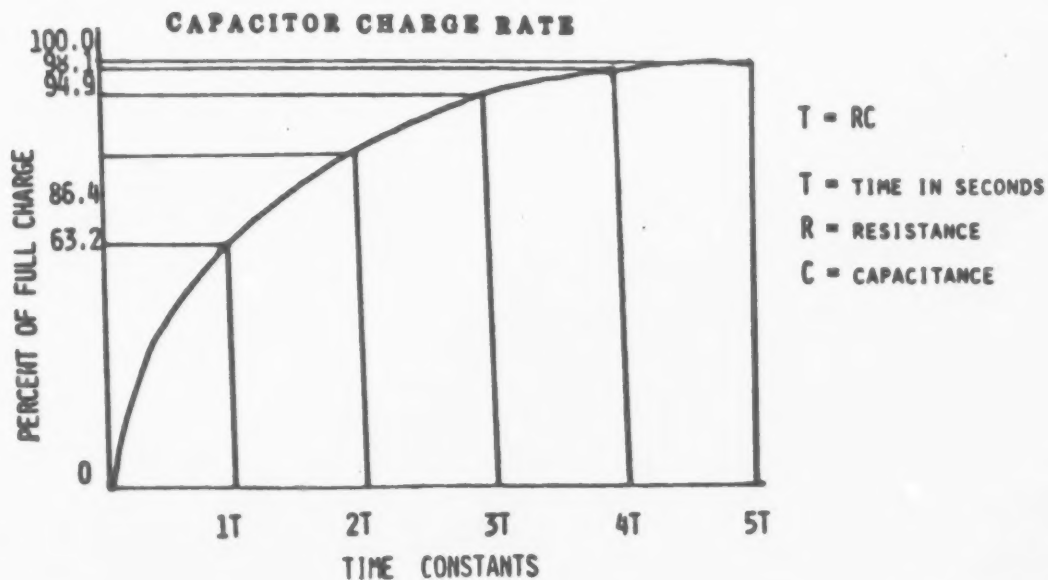
I = current in amps

R = resistance in ohms

7. Scientific notation



FUNCTION OF A CAPACITUR



TITLE: CASTER

CATEGORY: INNOVATION

DESCRIPTION:

The caster principle is the distance between the wheel contact and its swivel axis on a travel surface. This is usually achieved by tilting the steering axis from the vertical. If the steering axis leads the wheel, the caster is defined as being positive and the forces on the wheel cause it to travel in a straight direction. Bicycles use this principle to enhance stability. If the steering axis trails the wheel, the caster is defined as negative. A negative caster makes changing wheel direction easier. Automobiles with manual steering often use negative caster.

The characteristics of a steering system are largely dependent on the caster design.

SCIENCE CONCEPTS:

1. A force is required to change a direction of motion.
2. Friction is a force resisting motion.
3. Wheel drag opposes forward motion.
4. Vehicle weight is on the center of the tire contact patch.
5. Caster is the angle formed between the steering axis and a vertical line through the axle spindle.
6. Positive caster: the steering axis is in front of the center of the wheel contact patch.
7. With a positive caster, normal contact patch forces will force a wheel to follow directly behind the steering axis overcoming tendencies to veer from straight.

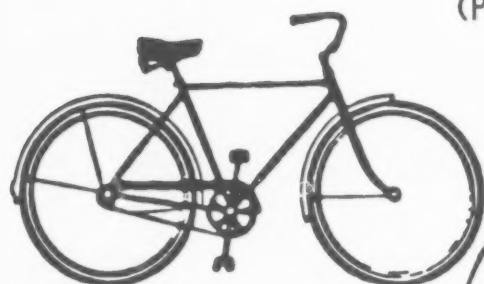
MATHEMATICAL CONCEPTS:

1. Geometric definitions--
angle--two rays with the same endpoint.
axis--a line used for reference.
radius--a segment with one endpoint as the center and the other on the circle.
2. Circumference of wheel (circle) $C = 2\pi r$ r = radius of wheel
3. Area of tire contact patch (rectangle) $A = l \times w$
4. Angle measurement in positive and negative degrees.

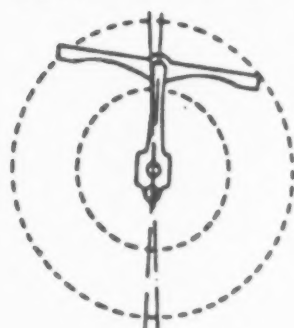
CASTER

BICYCLE APPLICATION

CASTER OF FRONT BICYCLE WHEEL
(POSITIVE CASTER)

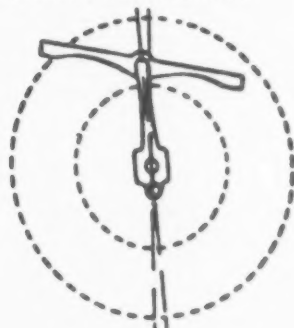


POSITIVE CASTER

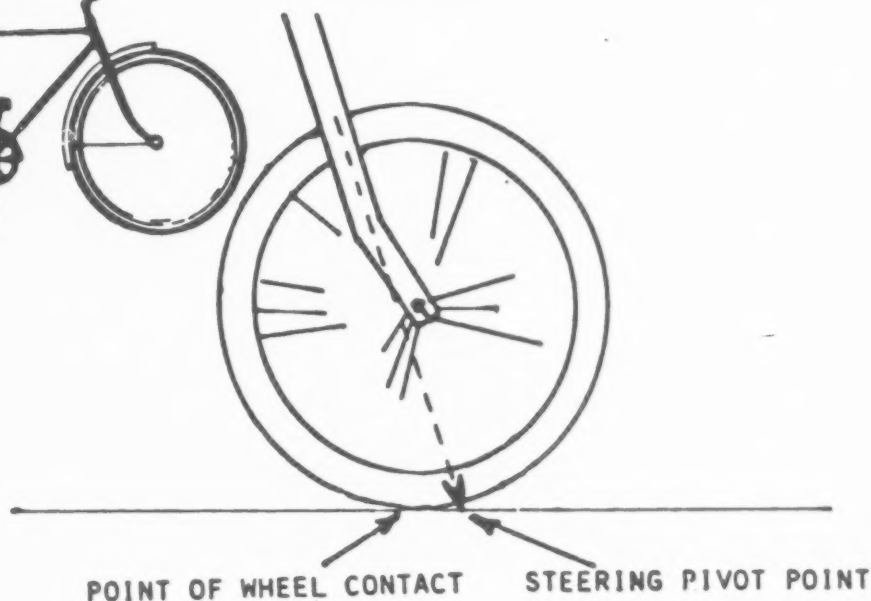


FORWARD

NEGATIVE CASTER



FORWARD



DIRECTION OF MOTION



SWIVEL
AXIS

WHEEL
CONTACT

RESISTANCE TO FORWARD MOTION

CASTER WHEEL TRAILS
DIRECTLY BEHIND PIVOT



DIRECTION OF MOTION

TITLE: CATALYTIC CONVERTER

CATEGORY: INNOVATION

DESCRIPTION:

To further reduce exhaust emissions, a great number of cars are equipped with CATALYTIC CONVERTERS. Properly designed converters, in good condition, produce significant reductions in the levels of hydrocarbon (HC) and carbon monoxide (CO). Nitrogen oxides (NO_x) are also lowered in converters containing RHODIUM as one of the catalyst agents.

A catalyst is a substance (platinum, palladium, or rhodium in this case) that will cause an increase in the rate of a chemical reaction (exhaust gases being burned). Yet, it will not be consumed or permanently altered by the reaction.

The converter(s) is inserted into the exhaust system between the exhaust manifold and muffler. As hot exhaust gases pass through the converter, they come into contact with the catalyst coating on the ceramic pellets or monolithic substrate, depending on construction. The catalyst causes a rapid rise in the temperature of the exhaust gas, causing the hydrocarbons, carbon monoxide, and to some extent, oxides of nitrogen to change (through an oxidizing process) into harmless water vapor, carbon dioxide, etc.

SCIENCE CONCEPTS:

1. Catalysis is the process of changing the speed of a chemical reaction by the presence of a substance which appears unaffected by the reaction.
2. A small quantity of catalyst is capable of effecting the transformation of an indefinitely large quantity of the reacting substance.
3. No catalytic agent can start a reaction; it merely modifies the speed of the reaction.
4. A catalyst has no effect on the final state of equilibrium between a forward reaction and any reverse reaction.
5. The velocity of two inverse reactions is affected to the same degree.
6. Homogeneous catalytic processes take place in a single, usually liquid, phase.
7. Heterogeneous catalytic processes take place in a multiple phase, usually in a gaseous environment, and usually in the presence of a solid catalyst.
8. Unburned hydrocarbons are oxidized in the presence of platinum (the catalyst) to form carbon dioxide and water vapor.
9. Carbon monoxide is oxidized in the presence of platinum to form carbon dioxide and water vapor.

SCIENCE CONCEPTS:

(CONTINUED)

10. Nitrogen oxides are reduced in the presence of a rhodium catalyst to form nitrogen and oxygen.
11. Carbon dioxide has a negative environmental impact. Increased carbon dioxide levels in our atmosphere are predicted to cause a gradual warming of the earth. This will result from the greenhouse effect.

MATHEMATICAL CONCEPTS:

1. Read and draw graphs.
2. Ratio apply to various situations.
3. Change temperature from Fahrenheit degrees to Celsius degrees. (Show the comparison of Fahrenheit to Celsius).

Example: Change the heat of catalyst from fahrenheit degrees to celsius degrees. The heat of the catalyst ranges from 900 degrees to 1600 degrees Fahrenheit.

$$C = (F - 32^{\circ}) \times \frac{5}{9}$$

$$C = (1600^{\circ} - 32^{\circ}) \times \frac{5}{9}$$

$$C = (900^{\circ} - 32^{\circ}) \times \frac{5}{9}$$

$$C = 1568^{\circ} \times \frac{5}{9}$$

$$C = 868^{\circ} \times \frac{5}{9}$$

$$C = 871^{\circ}$$

$$C = 482^{\circ}$$

PLATINUM

50 troy oz. - dollars per troy oz.

Jul.	430.50	434.00	427.50	431.90	+4.00
Oct.	434.50	439.50	431.00	435.90	+3.00
Jan.	440.00	442.00	435.50	438.90	+3.00
Apr.				441.90	+3.00
Jul.	447.50	447.50	445.50	445.40	+3.00

Est. Sales	Prv. Sales	Prv. Open Int.	Chg.
	7,339	19,154	-204

This information will be used to make a bar graph comparing prices of Platinum for 1986.

MATHEMATICAL CONCEPTS:

(CONTINUED)

This graph shows the effects of air/fuel ratio on our pollutants. Above 14.7 to 1 (leaner) the ability to control NO decreases. Below 14.7 to 1 (richer), the ability to control CO and HC decreases.

By staying in the "window" or approximately 14.7 to 1 air/fuel ratio, control of all three pollutants is best. This, then is the purpose of Computer Command Control . . . to maintain an air/fuel ratio of 14.7 to 1 under most driving conditions. Certain driving conditions do require richer mixtures which are explained in this manual.

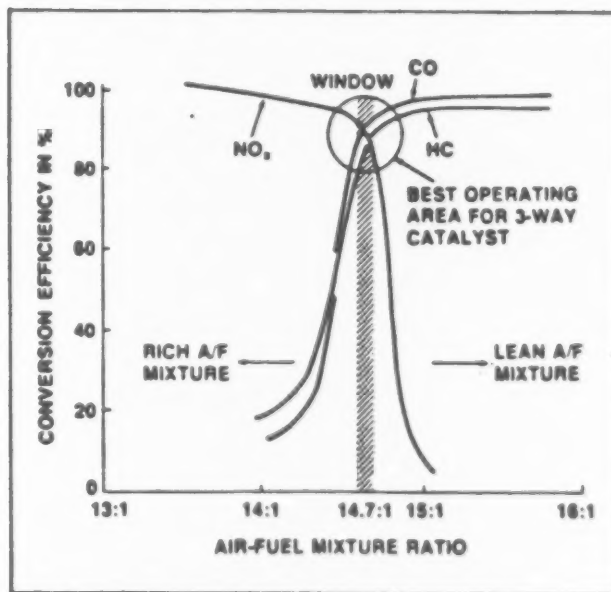
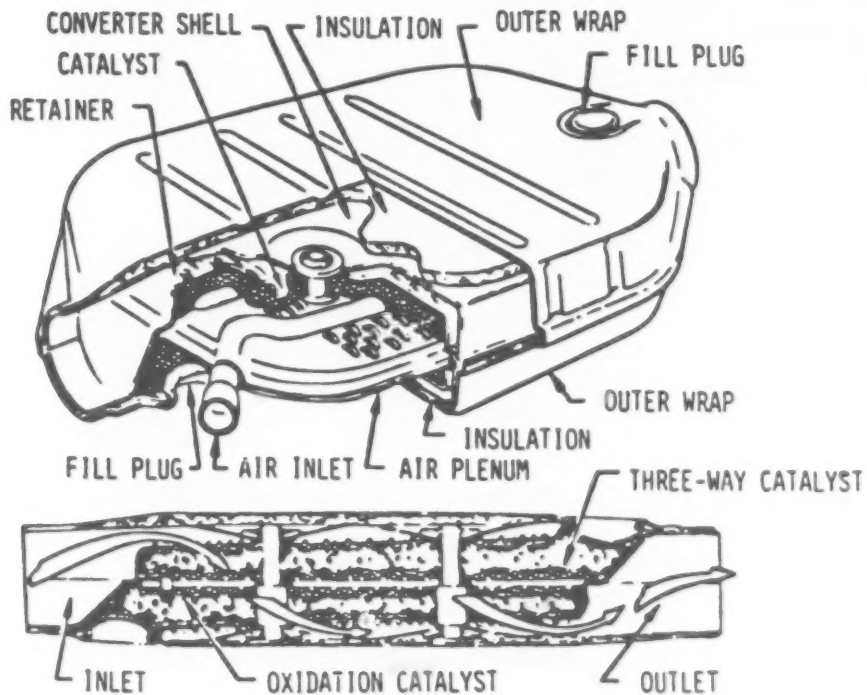
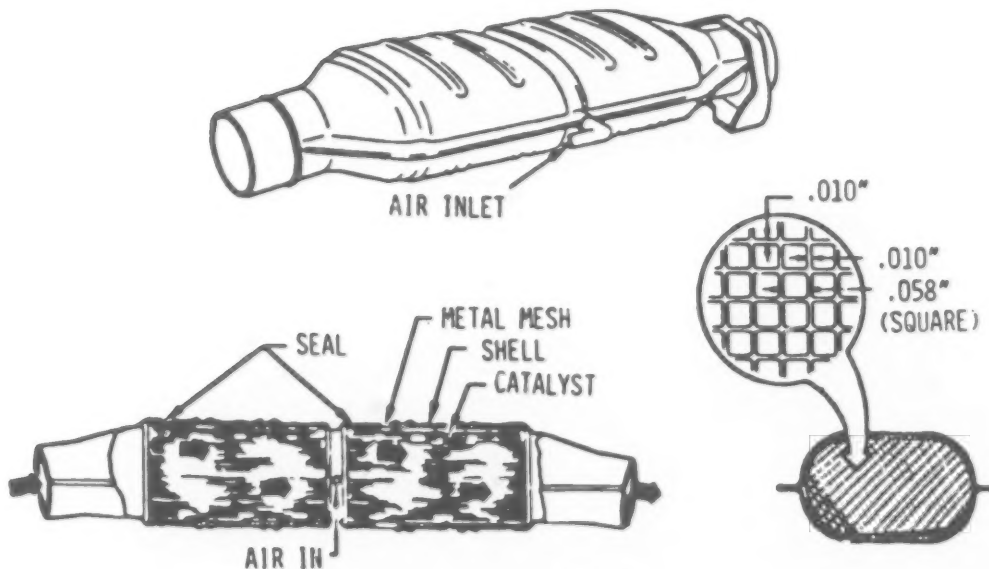


Figure 1-7, Principle of Operation 3-Way Catalyst.

CATALYTIC CONVERTER



PELLET TYPE



MONOLITH TYPE

Title: Combustion Cycle

Category: System

Description:

It was a Frenchman, Alphonso Beau de Rochas, who in 1862 proposed the four-stroke cycle. Beau de Rochas was a theorist and never built an engine. His ideas were not put in to practice until 1876 when a German engineer, Nikolous Otto, built the first prototype. In 1878 the four-stroke cycle engine was manufactured after a patent had been issued to Otto in 1877. Except in retrospect, man has generally admired doers more than thinkers. The four-stroke cycle bears the name of its developer, Otto, rather than its inventor, Beau de Rochas.

The combustion chamber receives 4 strokes.

1. Intake stroke - Air fuel mixture is sucked into the cylinder.
2. Compression stroke - Air fuel mixture is compressed.
3. Power stroke - Spark plug ignites air-fuel mixture.
4. Exhaust stroke - The burned up gases are pushed out of cylinder.

Science Concepts:

Celsius Temperature Scale

water freezes at 0° C

water boils at 100° C

Fahrenheit Temperature Scale

water freezes at 32° F

water boils at 212° F

Power = $\frac{\text{work}}{\text{time}}$ (Watts)

Work = Force X distance (joule)

Title: The Combustion Cycle

Category: System

Science Concepts:

States of matter - matter can exist in a liquid, solid, gas, or plasma state.

Energy - the ability to do work.

Law of conservation of matter - matter cannot be created nor destroyed, matter changes its state.

Kinetic energy - energy possessed by a moving object.

Potential energy - (stored energy) work that can be done by the object due to its relative position.

Expand - to increase in volume.

Contract - to decrease in volume.

Compound Machine - a machine made up of two or more simple machines.

Gas - the state of matter which lacks a definite shape or volume.

Horsepower - a unit of power equal in the U.S. to 746 watts.

Power - the amount of work done per unit of time.

Engine - a device that changes heat into mechanical energy.

Fractional distillation - a type of distillation in which compounds in petroleum are separated.

Gasoline - flammable liquid hydrocarbon mixture used as a fuel for internal combusting engines.

Chemical change - a change in which a substance becomes another substance having different properties.

Physical changes - a change in size, shape or state without a change in composition.

Heat transfer - heat is transferred in three ways:

(A). Conduction

(B). Convection

(C). Radiation

Title: Combustion Cycle

Category: System

Mathematical Concepts:

- 1). $A = \pi r^2$ Area of a circle = 3.14 X radius squared
- 2). $V = \pi r^2 h$ Volume of a cylinder = 3.14 radius squared X height
Height in this formula is length of stroke
- 3). Understanding of ratio as a comparison or rate.
- 4). $D = A \times S \times N$ Displacement = Area of Piston X Length of Stroke
X Number of Cylinders
- 5). $A = \frac{B}{C-1}$ A = Volume of combustion chamber
B = Volume of displacement
C = Desired compression ratio
- 6). Compression Ratio = $\frac{B.D.C}{T.D.C}$ (bottom dead center)
(top dead center)
- 7). Measurement Concepts
 - linear - both millimeters and inches
 - area - square inches (in.²) and millimeter square (mm²)
 - volume - (capacity) - cubic inches (in.³) and
cubic millimeters (mm³)

Title: Combustion Cycle

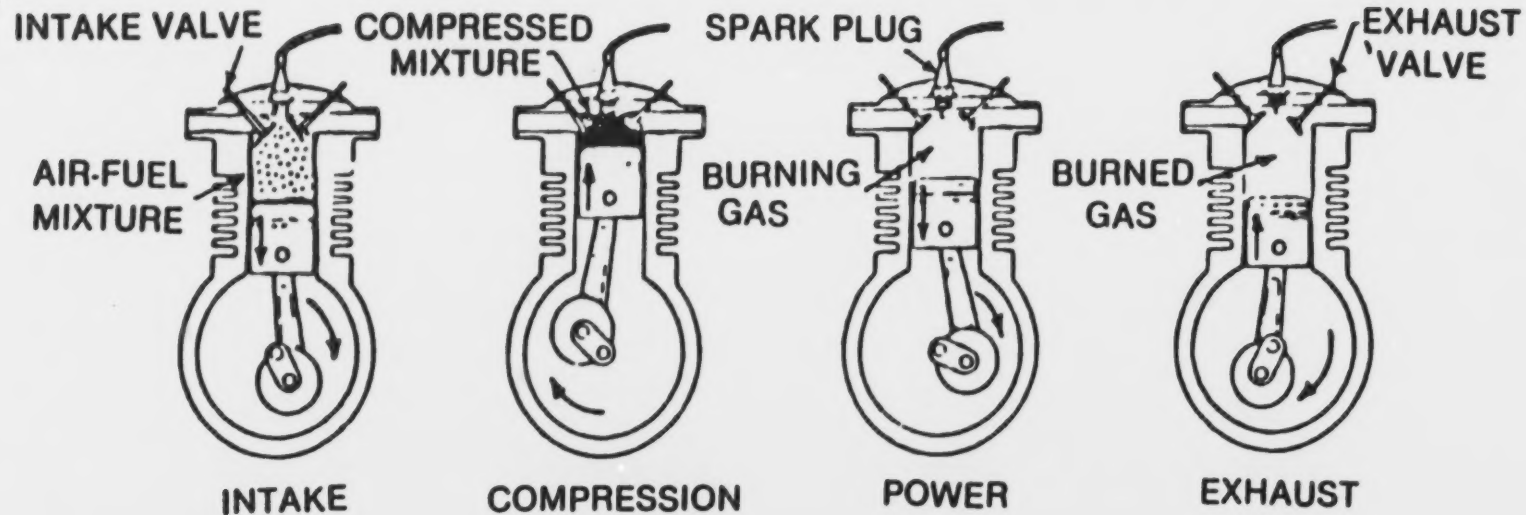
Category: System

Technological Impact:

Social Impact - The development of the automobile with its internal combustion engine has changed the way we live. This private means of transportation allows us to go where we want. No longer must one wait for a train or bus. With the automobile has come the growth of suburbs. People were able to move further away from the city. The automobile has required a massive growth and improvement in our highway system. The oil industry has greatly expanded due to the public's use of the automobile. The automobile industry employs many people. Annually many lives are lost on our highways.

Environmental Impact - Due to the volume of traffic on our highway and road systems each day we are now confronted with air pollution caused by automobile emissions. When highways and bridges are built there is an immediate impact on the existing communities and wildlife habitat.

COMBUSTION CYCLE



$$V = \pi r^2 h$$

V = VOLUME OF CYLINDER

h = LENGTH OF STROKE

r = RADIUS OR $\frac{1}{2}$ DIAMETER

$$\pi = 3.14$$

LAW OF CONSERVATION: MATTER CANNOT BE CREATED OR DESTROYED, MATTER CHANGES ITS STATE

STATES OF MATTER: MATTER CAN EXIST IN A LIQUID, SOLID, GAS, OR PLASMA STATE

TITLE: COMPUTER COMMAND CONTROL--"CLOSED LOOP" SYSTEM

CATEGORY: SYSTEM

DESCRIPTION:

Closed loop systems place a special oxygen sensor in the exhaust stream to constantly monitor emission levels.

As the oxygen sensor responds to emission changes, it sends an electrical signal to an electronic control unit. The control unit (computer) receives constant electric "signals" from the oxygen sensor. Based on the information from the oxygen sensor and other sensors such as engine temperature, car speed, engine rpm, atmospheric pressure, etc., the computer makes constant changes in the air-fuel mixture, engine timing, EGR (Exhaust Gas Recirculation), and other functions. This highly efficient system, in effect, constantly monitors its own exhaust, then makes the adjustments necessary to maintain the lowest possible emission levels, power and fuel economy.

SCIENCE CONCEPTS:

Turbocharger

1. The heat released when the spark plug ignites the compressed fuel-air mixture within the cylinder causes the pressure to increase suddenly (Gay-Lussac's Law). This drives the piston downward.
2. Engines change heat energy into mechanical energy.
3. Momentum = mass x velocity

In a turbocharger the momentum of the exhaust gases is transferred first to the turbine and then it is transmitted to the compressor. The compressor accelerates the incoming air. In this way the momentum is transferred to the incoming air. This transfer of momentum from the exhaust gas to the incoming air illustrates the Law of Conservation of Momentum.

4. Centrifugal force is the apparent pull away from the center when a body moves in a circle. Centripetal force is the force that keeps a body moving in a circle. If, at any time, the centripetal force stops acting on a body, it will obey Newton's First Law of Motion. Instead of moving in a line away from the center of the circle, it will move in a straight line that is a tangent to the circle of motion.

Catalytic Converter

5. Catalysis is the process of changing the speed of a chemical reaction by the presence of a substance which appears unaffected by the reaction.
6. Unburned hydrocarbons are oxidized in the presence of platinum (the catalyst) to form carbon dioxide and water vapor.
7. Carbon monoxide is oxidized in the presence of platinum to form carbon dioxide and water vapor.

SCIENCE CONCEPTS:

Catalytic Converter

(CONTINUED)

8. Nitrogen oxides are reduced in the presence of a rhodium catalyst to form nitrogen and oxygen.

Control System

9. Sensors pick up vital information about engine performance and transmit that information to the computer for processing.
10. Automobile sensors detect temperature, motion, oxygen concentration, speed, pressure, vibration and air flow.
11. Automobile sensors utilize variations in resistance, induction, electro-chemical response and switch position to control current. This information is transmitted to the computer.

Transistors are solid state devices which can amplify signals or act as switches similar in function to relays. They can use extremely small amounts of current to control large amounts of current.

12. Computers are devices which are capable of accepting digital information, processing that information using programmed instruction, and supplying the results of that processing. Automobile on-board computers are capable of making 250,000 calculations per second. These calculations are used to control air flow, amount of fuel and ignition timing to produce the most efficient burning of fuel under a variety of driving conditions.

TITLE: COMPUTER COMMAN CONTROL--"CLOSED LOOP" SYSTEM

CATEGORY: SYSTEM

MATHEMATICAL CONCEPTS:

1. Convert cubic centimeters to cubic inches.
2. Change cubic inches to cubic centimeters.
3. Change liters to cubic inches.
4. Ratio and proportion apply to various situations.
5. Problems using math terms (increase, decrease).
6. Point out the advantages of knowing how to use a formula.
7. Discuss the usage of the binary system.
8. Read and draw graphs.

Formula:

$$\frac{V_1 P_1}{T_1} = \frac{V_2 P_2}{T_2}$$

E = PN

C = AS

A = πr^2

$\pi = \frac{1}{2}B$

P = AS

cid - engine displacement

cm - cubic centimeter

cu. in. - cubic inches

l - liters

V - initial volume

V - final volume

t - time

E - engine displacement

C - cylinder displacement

N - number of cylinder

A - area of piston head

B - bore

π - pi

S - length of stroke

P₁ - initial pressure

P₂ - final pressure

MATHEMATICAL CONCEPTS:

(CONTINUED)

1. To convert cubic centimeters to cubic inches, multiply by 0.061
(cc x 0.061 = cu. in. or cid)
2. To change cubic inches to cubic centimeters, multiply by 16.39
(cu. in. or cid x 16.39 = cc)
3. To change over liters to cubic inches, multiply by 61.02
(liters x 61.02 = cu. in. or cid)

Example:

A 350-cid engine is also a 5736.5 engine. $350 \times 16.39 = 5736.5$

If expressed in liters, the displacement of the engine would be rounded to 5.7 liters (1 liter = 1000 cc.)

Find the cylinder displacement an engine displacement of an eight cylinder with a 4 inch bore and a 3.5 inch stroke.

Individual cylinder displacement equals

$$\pi r^2 \times L$$

$$3.1416 \times 2^2 \times 3.5 = 43.98 \text{ cid}$$

$$\text{Total displacement} = 43.98 \times 8 = 351.84$$

Total engine displacement 351.84 cu. in. Cu. in.

Example:

Find the engine displacement of an engine that has a Bore 8 cm, length of stroke(s) 7 cm, number of cylinder 6.

$$r = \frac{1}{2}B$$

$$r = \frac{1}{2} \times 8 \text{ cm}$$

$$r = 4 \text{ cm}$$

$$A = \pi r^2$$

$$A = 3.14 \times 4^2$$

$$A = 50.24 \text{ cm}$$

$$P = AS$$

$$P = 50.24 \text{ cm} \times 7 \text{ cm}$$

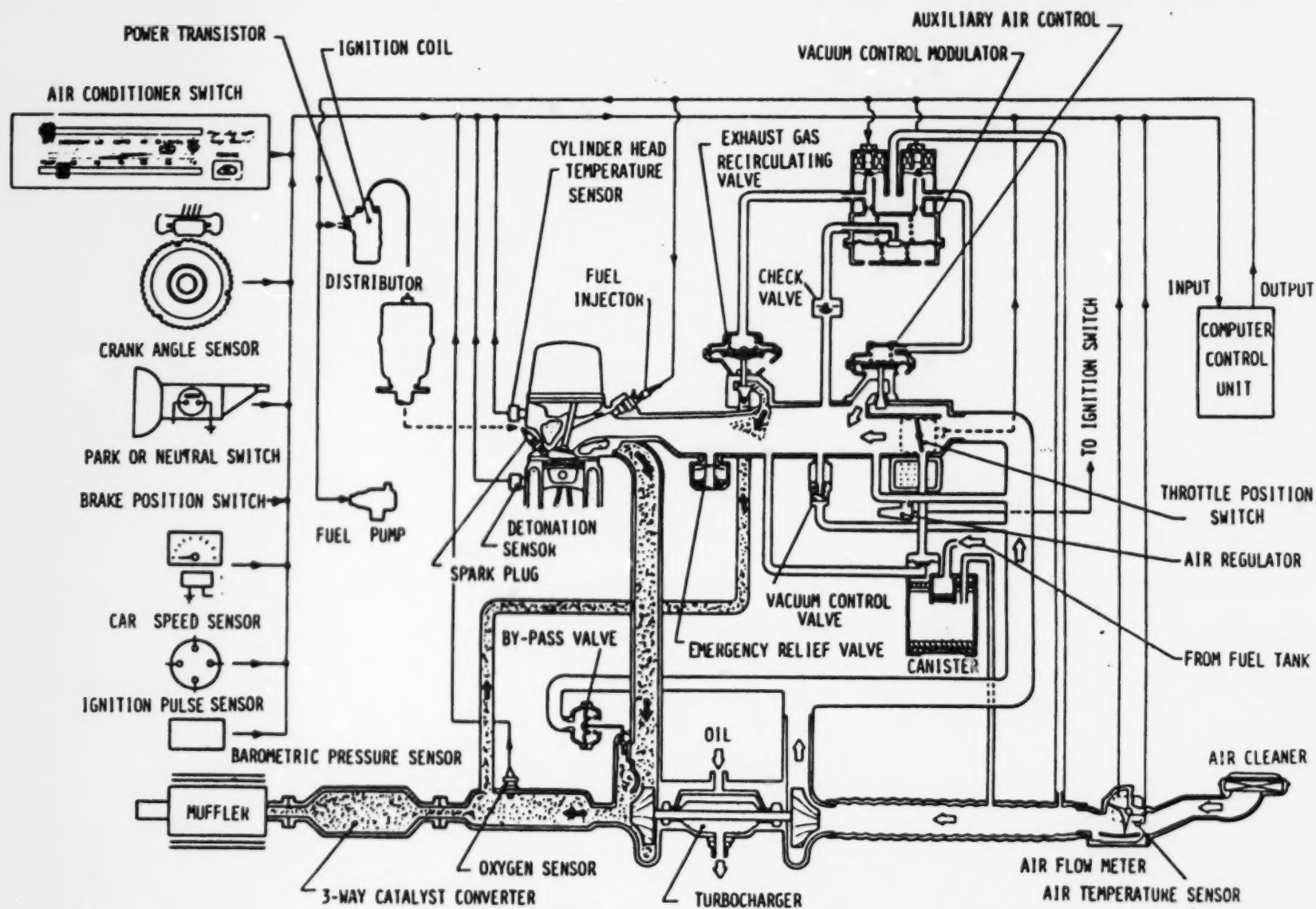
$$P = 351.68 \text{ cm}$$

$$E = PN$$

$$E = 35.68 \text{ cm}^3 \times 6$$

$$E = 2110.08 \text{ cm}^3$$

COMPUTER COMMAND CONTROL



105

"CLOSED LOOP" SYSTEM

106

BEST COPY AVAILABLE

TITLE: CONDUCTORS

CATEGORY: INNOVATION

DESCRIPTION:

Perhaps the greatest advantage of electric energy is that it can be carried great distances over wires with very little loss. A material with low resistance has a high conductance. Conductors force the electric current to follow desired paths. The larger the diameter of a wire, the greater its cross-sectional area, the less resistance the wire offers to current, thus it can carry more current safely.

SCIENCE CONCEPTS:

1. Electrons are negative charges of electricity.
2. Conductors transfer electrons from one atom to the next one in the conductor.
3. The valence electrons in a collection of metal atoms (that make up a wire), are said to be "delocalized." These electrons no longer belong to one metal nucleus, but rather, they belong to the whole group of metal nuclei.
4. Good conductors are elements that have one, two, or three loosely held valence electrons.
5. Metals are the best conductors.
6. Silver is the best conductor available.
7. Copper is an excellent conductor, and it is also the most widely used.
8. A coulomb is a measure of a certain amount of electrons. A coulomb equals 6.28×10^{18} electrons.
9. One coulomb per second is equal to one ampere of current.
10. The electrical pressure which forces current through a wire is voltage.
11. A galvanometer is an instrument that will indicate the presence of current.
12. An ammeter is a galvanometer that has been accurately calibrated.
13. Conductivity decreases as temperature increases.

TITLE: CONDUCTORS

CATEGORY: INNOVATIONS

MATHEMATICAL CONCEPTS:

1. Reciprocal relationships. Conductance is the reciprocal of resistance.
2. Concept of mil (1/1000 of an inch or .001 of an inch).
3. Division by 1000, movement of decimal point. Conversion of a measure in inches to mils.
4. Diameter of a circle is two times the radius ($d=2r$). Relate diameter and radius of a cross section of circular wire.
5. Area of a circle and approximate value of:

$$A = \pi r^2 \text{ or } A = \pi \left(\frac{d}{2}\right)^2 \text{ or } A = \pi \frac{d^2}{4}$$
$$\pi \doteq 3.14 \text{ or } \frac{22}{7}$$

Compute the area of a cross sectional area of circular wire in circular mils (cmil).

6. Direct proportional relationships. Find changes in conductance when cross sectional area changes.
7. Inverse proportional relationships. Find changes in conductance when wire length changes.
8. Use of the formula $R = \frac{\rho l}{A}$ to compute resistance and/or conductivity of a length of wire of given material and dimensions.

ρ = specific resistivity

l = conductor length

A = cross sectional area in cmils

8.-II Supplement to 8.

Why the formula produces a result in Ohms (cancellation of units).

First, the word "per" can be treated like division.

Example: Miles per hour is like $\frac{\text{miles}}{\text{hour}}$

and if you went 100 miles in (or per) 2 hours, that is:

$$100 \text{ miles per } 2 \text{ hours} = \frac{100 \text{ miles}}{2 \text{ hours}} = \frac{50 \text{ miles}}{1 \text{ hour}} = 50 \text{ miles per hour.}$$

Next, units can cancel too!

Example: If you went 50 miles per hour for 3 hours, that is:

$$\frac{50 \text{ miles}}{1 \text{ hour}} \times \frac{3 \text{ hours}}{1} = 150 \text{ miles} \quad \text{The hours cancel and the result is in miles.}$$

MATHEMATICAL CONCEPTS:

(CONTINUED)

Finally, $R = \frac{\rho l}{d^2}$ ρ is in Ohms per feet per cmil or $\frac{\text{Ohm}}{\frac{\text{feet}}{\text{cmil}}}$

l is in feet or $\frac{\text{feet}}{1}$

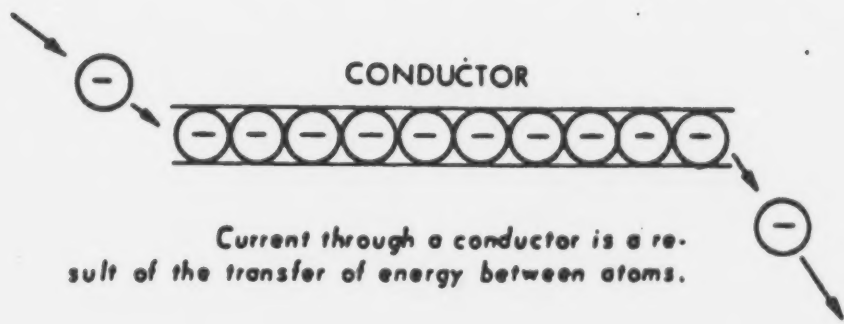
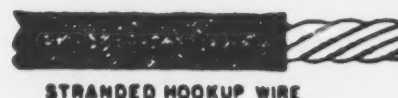
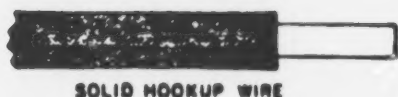
d^2 is in cmil or $\frac{\text{cmil}}{1}$

$$\text{thus } R = \frac{\text{Ohm}}{\frac{\text{feet}}{\text{cmil}}} \times \frac{\text{feet}}{1} = \frac{\text{Ohm}}{\frac{\text{cmil}}{1}} = \frac{\text{Ohm}}{\text{cmil}} \times \frac{\text{cmil}}{1} = \text{Ohm}$$

the unit of the answer is Ohms!!

9. Table reading. Use of tables to find resistances and specific resistances of various materials.

CONDUCTORS



WIRE CHARACTERISTICS

MATERIAL	SPECIFIC RESISTANCE
Silver	9.75
Copper	10.55
Aluminum	17.30
Nickel	53.00
Iron	61.00
Lead	115.00
Nichrome	660.00

CONDUCTOR RESISTANCE

$$R = \frac{\rho l}{d^2}$$

where: R = conductor resistance

ρ = specific resistance

l = conductor length in feet.

d^2 = cross-sectional area in circular mils.

TITLE: Resistance of Copper Wire

DESCRIPTION:

The resistance of wire varies directly with its length and inversely with its cross-sectional area. The dimensions of length and cross-sectional area are illustrated. The formula used to calculate the resistance of a conductor is presented. A simple comparison of three wires and the resistance of each is used to show the relationships of length to resistance and cross-sectional area to resistance. The resistance of a sample piece of copper wire is calculated as a practical example.

SCIENCE CONCEPTS:

1. Understanding resistance in a conductor current is the movement of free electrons. The amount of movement is controlled by the opposition to the movement of the electrons through a material. The opposition is called resistance.

The resistance of a substance depends upon how easily the electrons in the outer orbit can be displaced and moved, and upon the degree of collisions the moving electrons have with other atoms, ions or particles within the substance.

Resistance in a substance increases as length increases because electrons are more likely to collide with other things in the substance. Increasing the cross-sectional area of a substance decreases resistance because more outer orbit electrons are available for movement. Resistance may, also increase in a substance as its temperature increases because the atoms are vibrating more and the electrons are more likely to collide with atoms.

2. Understanding the conductivity of copper. Copper is considered to be an excellent conductor because it has only one easily movable electron in its outer orbit and therefore does not form covalent bonds with neighboring copper atoms. Instead it is believed that the copper atom effectively gives up its outermost electron with the remaining portion of the atom forming a positive ion. The positive ions are believed to form a metallic lattice with the valence electrons free to wander through the lattice and thus become carriers for electric current.

MATH CONCEPTS:

1. Applying the formula $R = \frac{\rho l}{A}$ in order to find resistance.
2. Finding the cross-sectional area of a wire given its diameter.
3. Reading and interpreting tables of resistivity.
4. Understanding exponential notation and applying the laws of exponents: $b^x \cdot b^y = b^{x+y}$; $\frac{b^x}{b^y} = b^{x-y}$, $b \neq 0$
 $b^{-x} = \frac{1}{b^x}$
5. Working with proportion: the resistance of a wire is directly proportional to its length; the resistance of a wire is inversely proportional to its cross-sectional area.
6. Finding the length or diameter of wire needed to make a certain resistance by taking the formula

$$R = \frac{\rho l}{A} \quad \text{and solving for } l \text{ or } A.$$

7. Determining how much the resistance changes for a given change in temperature. This factor, represented by α , is seen in the formula $R = R_0 + R_0 (\alpha \Delta t)$ where R is the resistance at 20°C , R_0 is the higher resistance at the higher temperature and Δt is the temperature rise above 20°C . In practical terms a positive α means that heat increases R in wire conductors, and I is reduced with a specified applied voltage. A negative value of α means less resistance at higher temperatures. A zero α means R is constant with changes in temperature.
8. Understanding terms and symbols of measurement:
 - a. Δ - Greek letter delta representing change.
 - b. ρ - Greek letter rho representing resistivity.
 - c. mil - one-thousand of an inch.
 - d. inversely proportional-relationship between dependent quantities so that as one increases the other decreases.
 - e. circular mil - the cross-sectional area of a wire with a diameter of 1 mil. The number of circular mils in any circular area is equal to the square of the diameter in mils, to see why this is so, we apply the formula for area of a circle, πr^2 . Since $r = \frac{d}{2}$, the formula becomes approximately $\pi (\frac{d}{2})^2 = \frac{3.14}{4} \times d^2$ which becomes .7854d . If "d" is in mils, then the area would be .7854 square mils. By definition of circular mil, the area of a cross section with diameter 1 mil would be .7854 x (1)² or .7854 square mils. Therefore, if we divide .7854d² by .7854, we discover the area in circular mils is simply d² .

RESISTANCE OF COPPER WIRE

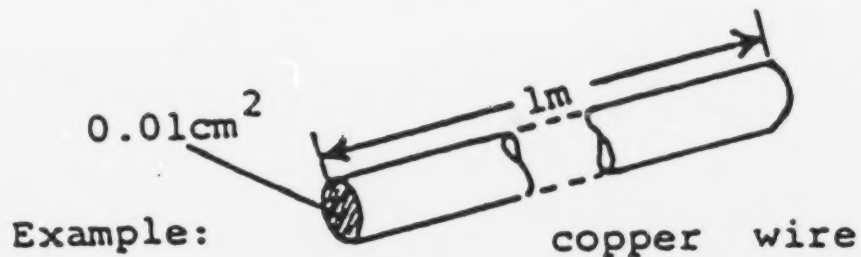
R = resistance (ohms)

ρ = resistivity (ohms/cm)

l = length of wire (cm)

A = cross-sectional area (cm^2)

$$\rho = 1.724 \times 10^{-6} \text{ for copper}$$



Find the resistance

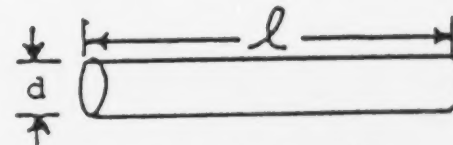
$$R = \frac{\rho l}{A}$$

$$R = \frac{1.724 \times 10^{-6} \times 100}{10^{-2}}$$

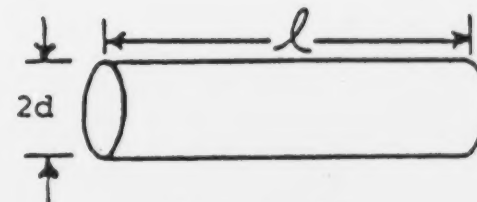
$$R = 1.724 \times 10^{-2}$$

$$R = 0.01724 \text{ ohms}$$

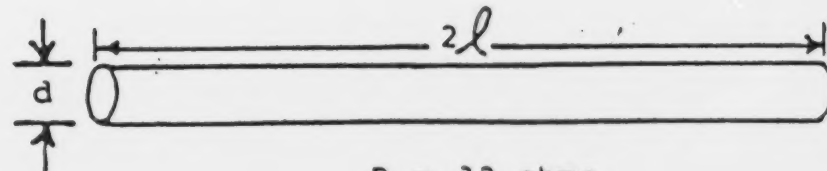
Comparing
Wire Diameter and Length



$$R = 16 \text{ ohms}$$

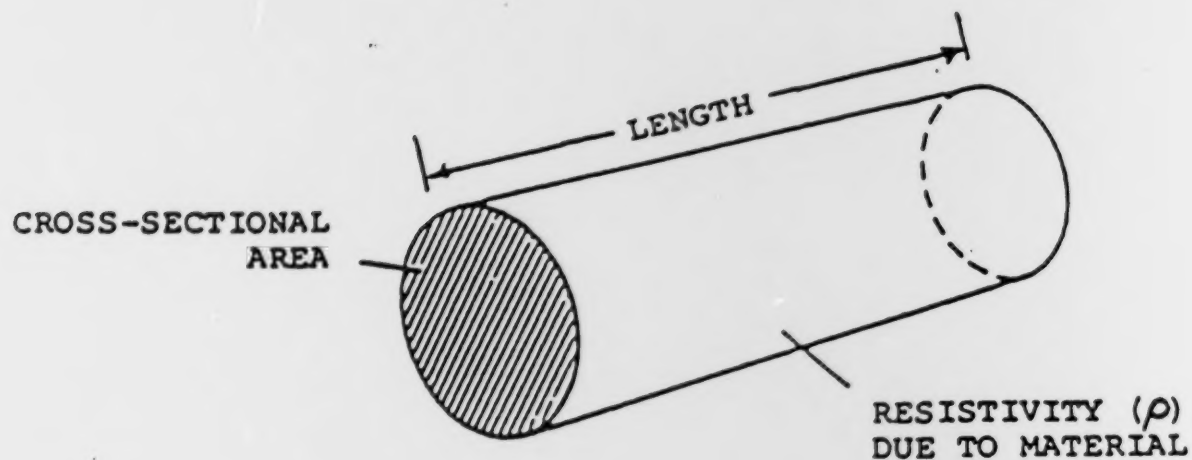


$$R = 4 \text{ ohms}$$



$$R = 32 \text{ ohms}$$

RESISTANCE OF COPPER WIRE



$$R = \frac{\rho l}{A} \quad \text{where}$$

R = resistance (ohms)

ρ = resistivity (ohms/cm)

l = length of wire (cm)

A = cross-sectional area (cm^2)

$\rho = 1.724 \times 10^{-6}$ for copper

TITLE: Diesel Compression Ratios

DESCRIPTION:

This transparency presents diagrammatically the compression ratio of the diesel engine. The mathematical and scientific concepts are depicted so as to develop a transition between Industrial Arts, Math, and Science.

SCIENCE CONCEPTS:

1. Kinetic Molecular Theory - Molecules of matter are constantly in motion. As you increase the temperature of a gas, the speed of the gas molecules also increases. Therefore, as you decrease the temperature of a gas the speed of the gas molecules also decreases.

During the compression stroke of a diesel engine, the piston compresses the air in the cylinder to such a great degree that the molecules are moving so fast and colliding with the cylinder walls with such a great speed, that the temperature of the air within the cylinder is extremely high. The temperature of the cylinder, during the compression stroke and right before the diesel fuel is injected, can reach at least 1100 ° F. Due to the high temperature achieved within the diesel engine cylinder (which is much higher than that of a traditional gasoline engine) a spark plug is not needed. When the fuel is injected it burns immediately due to high temperatures.

2. Expansion of Gases - When gas molecules are heated they will expand. After the diesel fuel is injected into the hot cylinder it will burn and the gas molecules will expand forcing the piston downward.
3. Chemical Change - This change takes place when two or more substances combine during a chemical reaction and the product achieved is a new, different product. (Ex. Diesel Fuel and Air → Exhaust).
4. % Efficiency = $\frac{\text{Work Output}}{\text{Work Input}} = \frac{\text{work delivered}}{\text{heat supplied}}$

Most automobile diesel engines are anywhere from 46% to 53% efficient. In relationship to the traditional gasoline engines this is a higher % efficiency than that achieved in gasoline engines.

MATH CONCEPTS:

1. Area of a circle. This piston head is circular in shape, so the area is found by using the formula
 $A = \pi r^2$ where $\pi = 3.14$ and $r =$ radius of the circle.
2. Volume of a cylinder. The volume of a cylinder is found by taking the area of the base times the height
($V = \pi r^2 h$).
3. Comparison of ratios. Compression ratios are given with a denominator (bottom number in fraction) of 1. The higher the numerator (top number of a fraction), the higher the ratio.

4. From the Industrial Arts concept

$$\text{Compression ratio} = \frac{(\text{Area of piston head}) \times (\text{head-height plus cylinder height; piston at bottom dead center})}{(\text{Area of Piston head}) \times (\text{head-height; piston at top dead center})}$$

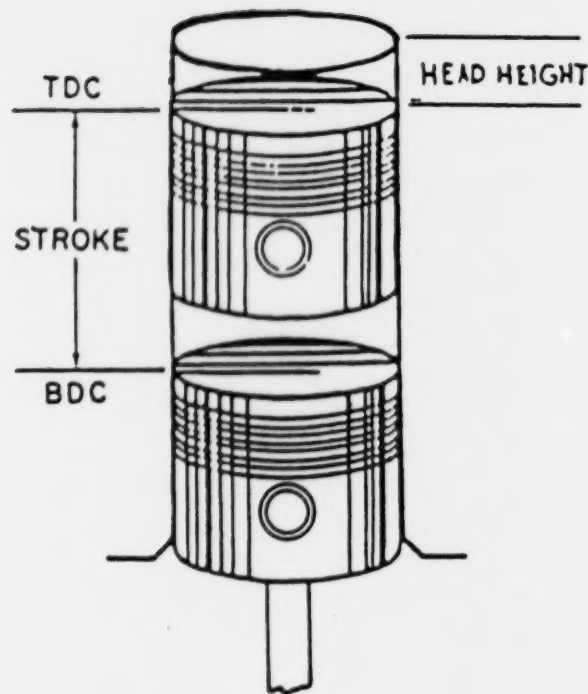
$$\text{Evolves the mathematical formula } CR = \frac{(\pi r^2) (P_{BDC})}{(\pi r^2) (P_{TDC})}$$

$$\text{The areas divided out leaving } CR = \frac{P_{BDC}}{P_{TDC}}$$

5. Compression ratio is often confused with displacement because each is related to piston position and to cylinder volume. Displacement is the cubic inch or cubic centimeter volume displaced or swept by all the piston in one revolution of the crankshaft. The displacement of one cylinder is multiplied by the number of cylinders in the engine to find the total engine displacement.

DIESEL COMPRESSION RATIO

COMPRESSION RATIO



$$CR = \frac{(\pi r^2)(P_{BDC})}{(\pi r^2)(P_{TDC})}$$

The area of the piston head (πr^2) remains the same, so

$$CR = \frac{(P_{BDC})}{(P_{TDC})}$$

CR = Compression Ratio

$\pi = 3.14$

P_{BDC} = head height plus cylinder height
piston at bottom dead center

P_{TDC} = head height
piston at top dead center

DIESEL COMPRESSION RATIO

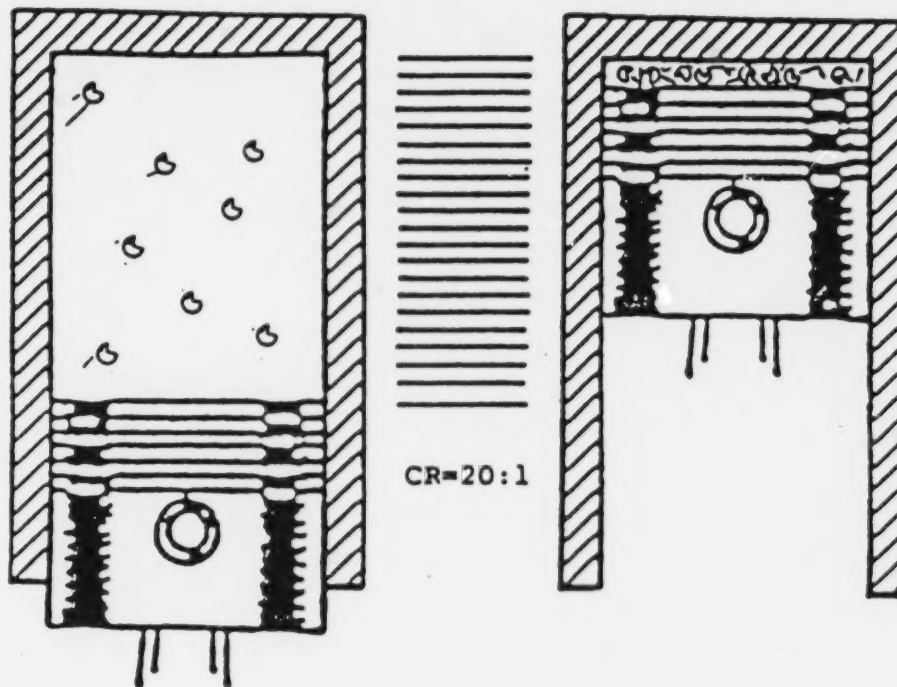
KINETIC MOLECULAR THEORY

As the pressure increases:

- A. temperature increases.
- B. molecules move faster.

Thus:

injected fuel
is burned.



TITLE: DIODES

CATEGORY: INNOVATION

DESCRIPTION:

Diodes are devices that allow current to flow only in one direction. By properly placing a diode, or diodes, in a circuit, it is possible to control current by controlling the direction of the current.

In a forward-biased p-n diode, whole electron pairs are continuously being formed and recombining. The recombination releases energy, which for certain materials is manifest as visible light. The most popular of these is the light emitting diode (LED), which employs gallium arsenide or gallium phosphide as a semiconductor material.

SCIENCE CONCEPTS:

1. Diodes pass current in one direction but block it in the other direction.
2. The arrow of the diode symbol points the direction of allowed conventional current (positive to negative). Electron flow is against the direction of the arrow.
3. Bands or bars at one end of the diode points to flow direction.
4. Silicon junction diodes are the most common type, drop about 0.6 V when passing currents less than 10 mA and about 0.9 V when forward current is greater than 10 mA.
5. Current passage in diodes varies from unit to unit and with temperature.
6. Diodes act as rectifiers by offering high resistance to current flowing in one direction but little resistance to current flowing in the opposite direction.
7. Diodes are used to rectify alternating current as a main supply to a direct current supply used by radios, computers, and t.v.'s.
8. Solid-state Diode types:

Approximation for diode forward voltage drop:

	10 mA or less	Above 10 mA
1. Germanium point contact	0.2v	0.5v
2. Germanium junction		
3. Silicon junction	0.6v	0.9v
4. Schottky or hot-carrier	0.3v	0.6v
5. Light-emitting	1.4v	1.4v

TITLE: DIODES

CATEGORY: INNOVATION

MATHEMATICAL CONCEPTS:

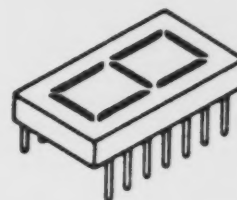
1. Use of Ohm's Law $I = \frac{V}{R}$ where I = electric current (amperes)
 V = electromotive force (volts)
 R = resistance (ohms)
2. Division of decimals.
3. Graphing in a rectangular coordinate system.
4. Graphing functions: linear, quadratic, hyperbolic.
5. Concepts of limits and infinity.
6. Use of signed numbers.

DIODE

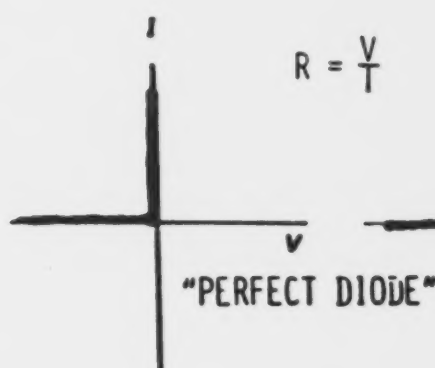
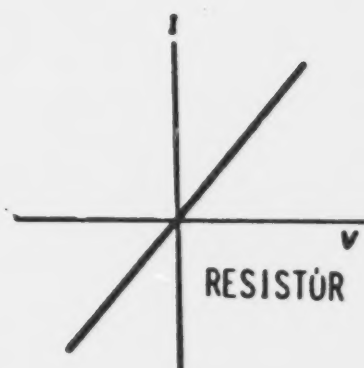
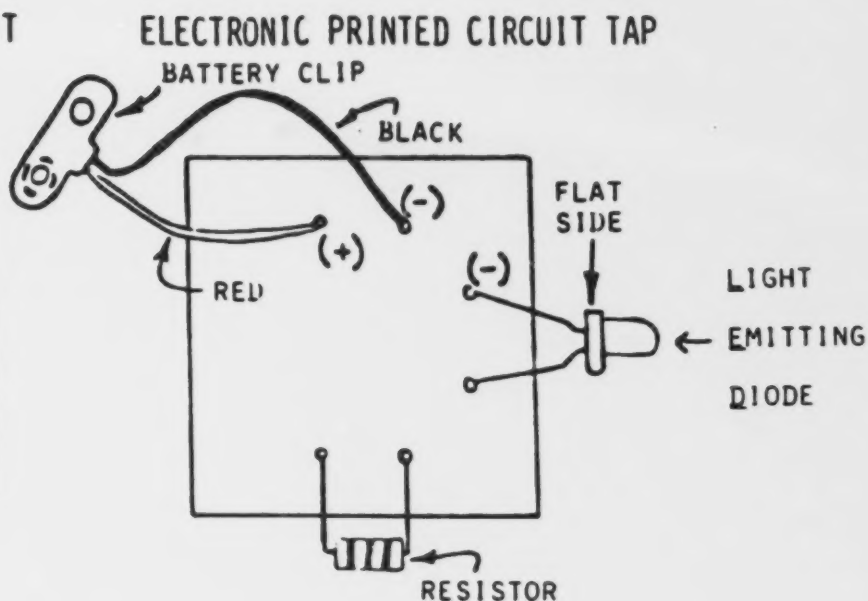
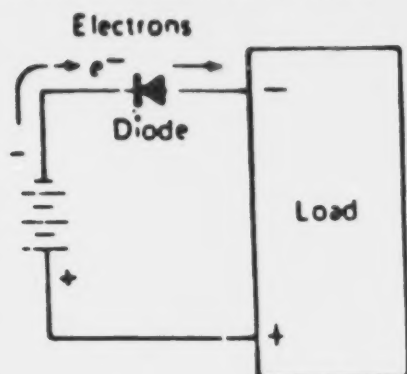
A TWO-TERMINAL DEVICE THAT CONTROLS CURRENT IN ONE DIRECTION ONLY.



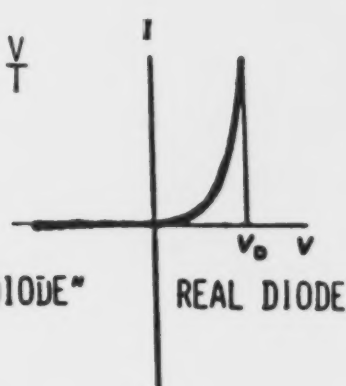
DIODE SYMBOL



DIODE IN A SERIES CIRCUIT WITH A 220Ω RESISTOR



$$R = \frac{V}{I}$$



COMPARISON WHEN FORWARD BIAS IS APPLIED TO A 'PN' JUNCTION

TITLE: DRY CELL

CATEGORY: INNOVATION

DESCRIPTION:

The dry cell is used when it is impractical to use a battery with a liquid electrolyte. Since a dry cell's electrolyte is moist and not wet, it may be carried in any position without the danger of spilling acid (electrolyte) on living organisms or on the instrument requiring the energy.

SCIENCE CONCEPTS:

1. Electrical energy--the kind of energy that moving charges have.
2. Repel--push away.
3. Attract--pull together.
4. Electron--a tiny particle with a negative charge.
5. Proton--a tiny particle with a positive charge.
6. Electrode--the negative or positive part of an electrical cell.
7. Electrolyte--a liquid or moist substance that conduct electricity.
8. Dry cell--an electrical cell that has a moist electrolyte.
9. Terminal--the negative or positive end of an electrical cell.
10. Current--the movement of charge in a conductor.
11. An electric current always moves from a negative terminal to a positive terminal.
12. Resistance--a measure of how easy or hard it is for electric current to move through a material.

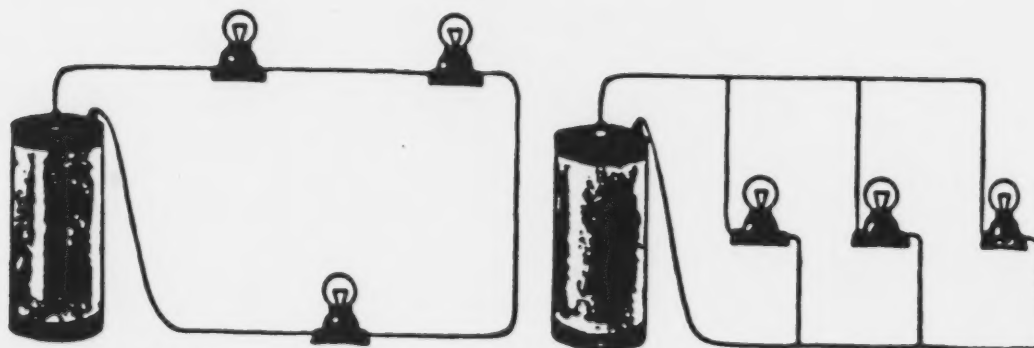
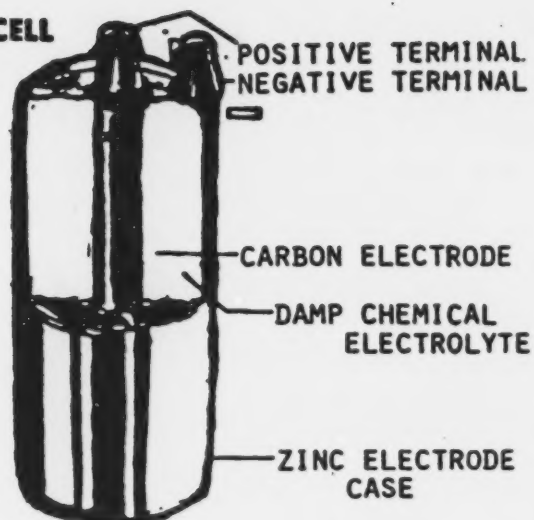
MATHEMATICAL CONCEPTS:

The following formula does not directly relate to the functioning of the dry cell. However, it does apply to resistance which will be taught later in the unit.

$$\text{electric current (amperes)} = \frac{\text{electromotive force (volts)}}{\text{resistance}}$$

DRY CELL

DRY CELL



USES OF DRY CELL

POWER SOURCE FOR: FLASHLIGHTS
CHILDREN'S TOYS
CALCULATORS
RADIOS
TAPE RECORDERS
TELEVISIONS

TITLE: RELATIONSHIP OF CORE PERMEABILITY TO ELECTROMAGNETIC FIELD STRENGTH

CATEGORY: RESEARCH AND EXPERIMENTATION

DESCRIPTION:

Electromagnetic field strength is directly affected by the number of coil turns, the coil current, and the permeability of the core material. Permeability is the property of a core material to increase electromagnetic field strength relative to an air core.

Electromagnetic field strength is measured in terms of imaginary force lines called lines of flux. A line of flux is a line, a tangent to which at any point indicates the direction of the magnetic field, north to south. Magnetic lines of flux can be referred to as magnetic flux, where 10 lines of flux equal one Weber. Magnetic flux density (B) is a measure of flux lines per unit area that permeate the magnetic field, and this is measured in units of Webers per square meter or Teslas.

While flux density cannot be measured directly, the effect of increasing or decreasing flux density can be measured.

By constructing an electromagnetic coil with a fixed number of turns and a constant coil current, the effects of different materials on permeability may be measured. A glass vacuum tube will be used as a control in order to discount any effect of the glass and stopper as the core material. All other materials will be placed into the coil core by the glass test tube and related to an air test tube with a standard value of one.

A change in the core material of an electromagnet should result in a detectable change in electromagnetic field strength. The change, as it relates to an air core with a value of one, may be measured by the needle deflection in a grid of compasses or by a magnetometer.

SCIENCE CONCEPTS:

1. When an electric current flows through the coils around a core, an electromagnetic field is produced.
2. The polarity of the magnetic field is relative to the direction of the current flow, as defined by the Left Hand Coil Rule.
3. The Left Hand Coil Rule states that if the coil is grasped in the left hand, with the fingers circling the coil in the direction of the current, the extended thumb will point in the direction of the North pole of the core.
4. The electromagnetic field generated can be measured by using compasses placed around the coil or by using a magnetometer.
5. A magnetometer is an electronic device that measures the electromagnetic field strength.

SCIENCE CONCEPTS:

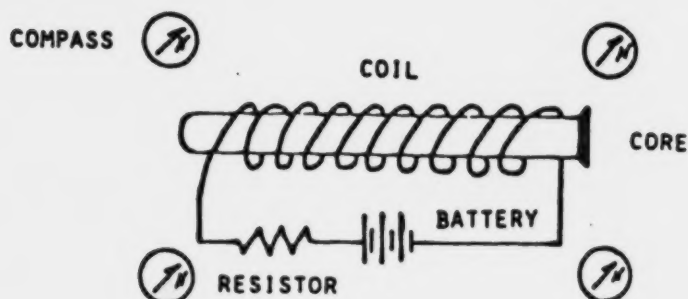
(CONTINUED)

6. The electromagnetic field produced varies in direct proportion to the permeability of the core, as well as to the number of coil turns and the current flowing through the coil.
7. Permeability is the property of a core material to increase electromagnetic field strength relative to an air core.
8. Varying the core material will yield measurable electromagnetic field strength changes due to the changes in core permeability.

MATHEMATICAL CONCEPTS:

1. Comparative graph analysis.
2. Flux lines are loosely called lines of force.
3. All flux lines are called magnetic flux (Φ).
4. 1 Weber = 10^8 lines of flux
5. $B = \frac{\Phi}{\text{Area}}$ Where B = Magnetic Flux Density
6. $B = \mu NI$ Where:
 μ = permeability
N = number of coil turns
I = current flowing through coil

RELATIONSHIP OF CORE PERMEABILITY TO ELECTROMAGNETIC FIELD STRENGTH



MATH CONCEPTS

1. COMPARATIVE GRAPH ANALYSIS
2. FLUX LINES ARE LOOSELY CALLED LINES OF FORCE.
3. ALL FLUX LINES ARE CALLED MAGNETIC FLUX (Φ).
4. 1 WEBER = 10^8 LINES OF FLUX
5. $B = \frac{\Phi}{\text{AREA}}$ WHERE B = MAGNETIC FLUX DENSITY
6. $B = \mu NI$ WHERE:
 μ = PERMEABILITY
 N = NUMBER OF COIL TURNS
 I = CURRENT FLOWING THROUGH COIL

SCIENCE CONCEPTS

1. WHEN AN ELECTRIC CURRENT FLOWS THROUGH THE COILS AROUND A CORE, AN ELECTROMAGNETIC FIELD IS PRODUCED.
2. THE POLARITY OF THE MAGNETIC FIELD IS RELATIVE TO THE DIRECTION OF THE CURRENT FLOW, AS DEFINED BY THE LEFT HAND COIL RULE.

3. THE LEFT HAND COIL RULE STATES THAT IF THE COIL IS GRASPED IN THE LEFT HAND, WITH THE FINGERS CIRCLING THE COIL IN THE DIRECTION OF THE CURRENT, THE EXTENDED THUMB WILL POINT IN THE DIRECTION OF THE NORTH POLE OF THE CORE.
4. THE ELECTROMAGNETIC FIELD GENERATED CAN BE MEASURED BY USING COMPASSES PLACED AROUND THE COIL OR BY USING A MAGNETOMETER.
5. A MAGNETOMETER IS AN ELECTRONIC DEVICE THAT MEASURES THE ELECTROMAGNETIC FIELD.
6. THE ELECTROMAGNETIC FIELD PRODUCED VARIES IN DIRECT PROPORTION TO THE PERMEABILITY OF THE CORE, AS WELL AS TO THE NUMBER OF COIL TURNS AND THE CURRENT FLOWING THROUGH THE COIL.
7. PERMEABILITY IS THE PROPERTY OF A CORE MATERIAL TO INCREASE ELECTROMAGNETIC FIELD STRENGTH RELATIVE TO AN AIR CORE.
8. VARYING THE CORE MATERIAL WILL YIELD MEASURABLE ELECTROMAGNETIC FIELD STRENGTH CHANGES DUE TO THE CHANGES IN CORE PERMEABILITY.

TITLE: ELECTROMAGNETIC RELAY

CATEGORY: INNOVATION

DESCRIPTION:

The relay, one of the oldest electrical devices, continues to be used as a control in mechanical systems of today. It is comprised of an iron core coil which is placed in close proximity to a set of electrical contacts. This electro-mechanical device can use a low power circuit to activate the electro-magnet coil. The magnetic field provided by this coil activates a set of heavy duty contacts which are capable of controlling high power devices. Relays can control a variety of different contact arrangements to meet specific electrical needs.

SCIENCE CONCEPTS:

1. The flow of electrons is an electric current.
2. Metals are good conductors of electric current because they have many electrons relatively free to move.
3. Voltage is a potential difference between two points.
4. High power circuits require high voltage and/or current.
5. Relays can use low power to control high power circuits.
6. A current produces a magnetic field.
7. The force of a magnetic field in a coil is proportional to the number of windings and the current.
8. Any substance will alter a magnetic field. A ferromagnetic core will magnify the field of current flowing through a coil.
9. A ferromagnetic substance has domains of uncanceled randomly arranged magnetic fields. In the presence of an external magnetic field, the domains realign and reinforce the external field.
10. Ferromagnetics are attracted by magnets and can carry current.

TITLE: ELECTROMAGNETIC RELAY

CATEGORY: INNOVATION

MATHEMATICAL CONCEPTS:

1. Ratio and proportion

2. $I = V/R$

I = current in amps

V = voltage

R = resistance in ohms

3. $P = VI$

P = power in watts

V = voltage

I = current

4. $P = I^2 R$

P = power

I = current

R = resistance

5. $B = \mu \cdot \frac{N}{L} \cdot I$

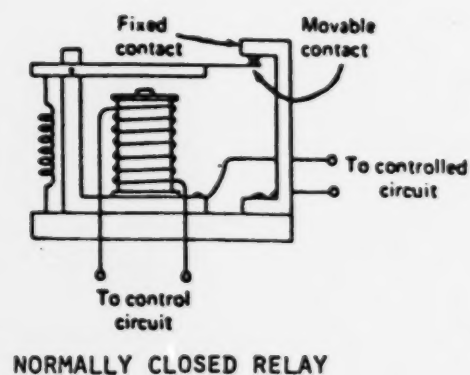
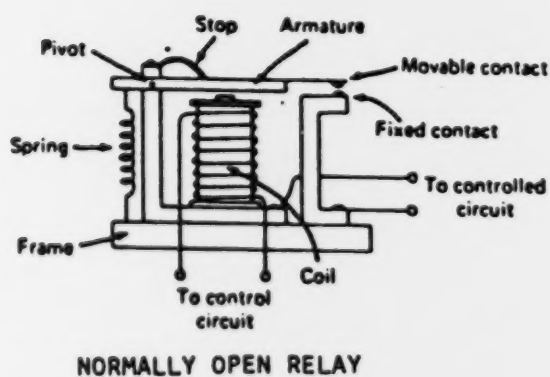
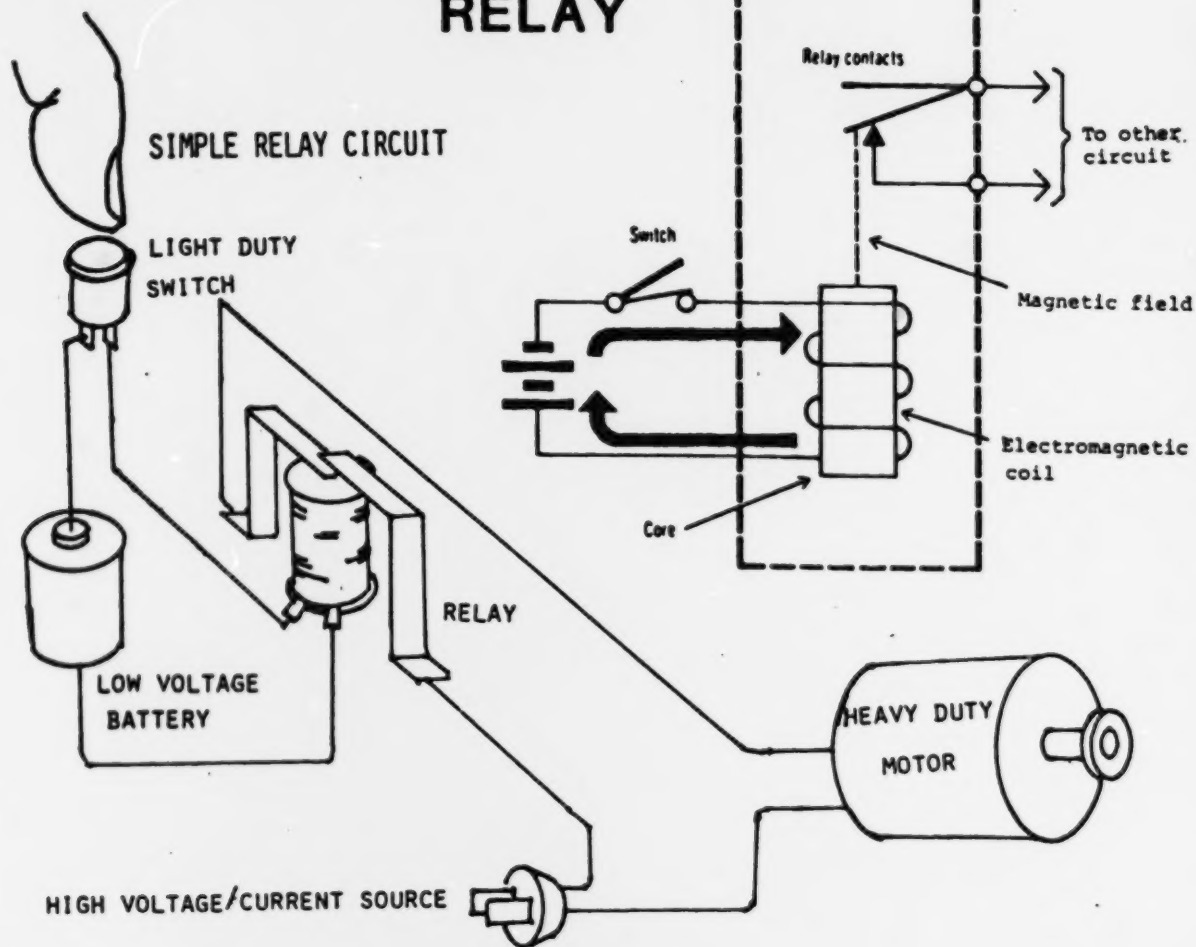
B = magnetic field in teslas

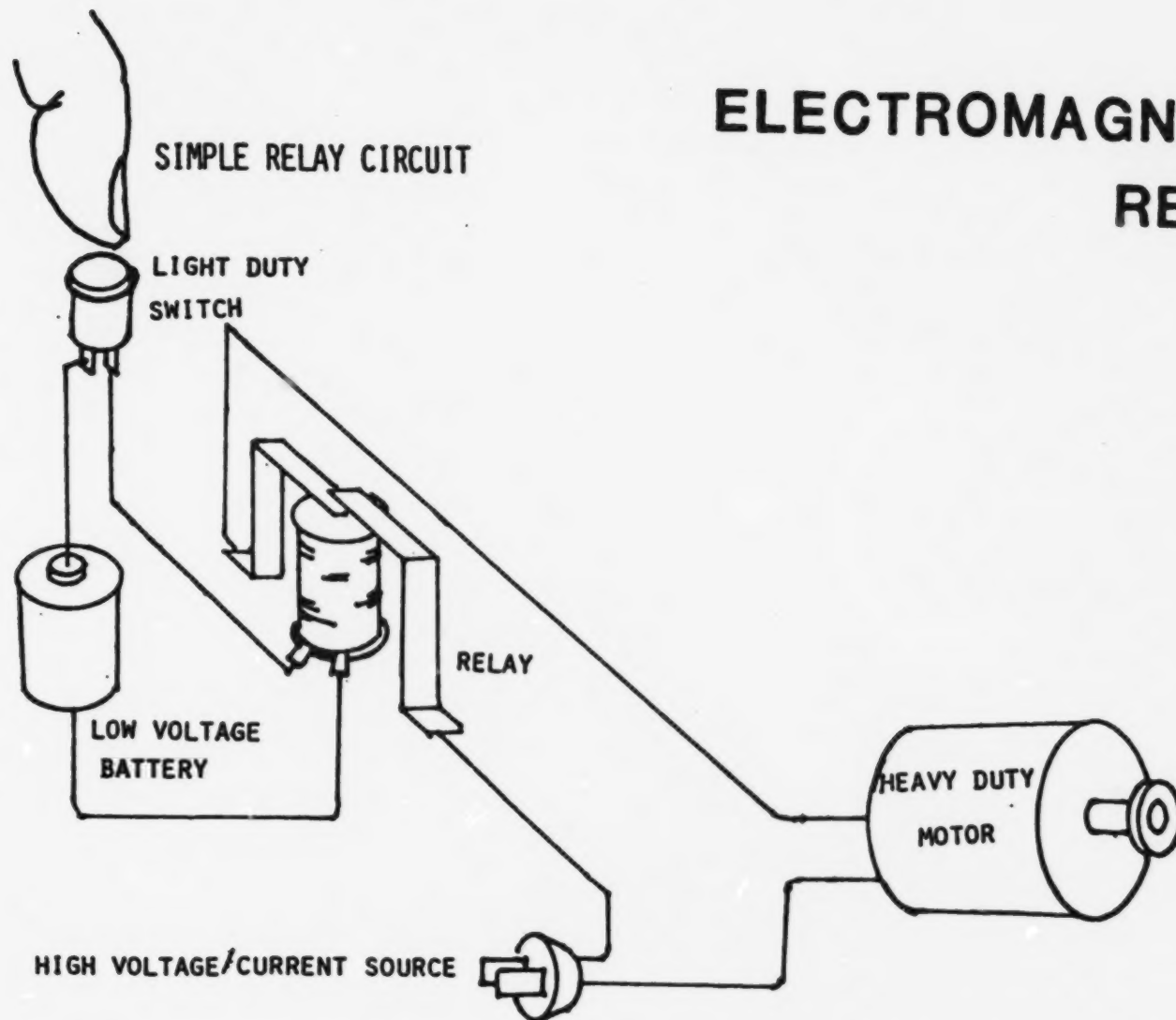
μ = permeability in tesla-meters/amp

N = number of turns of the wire in the coil

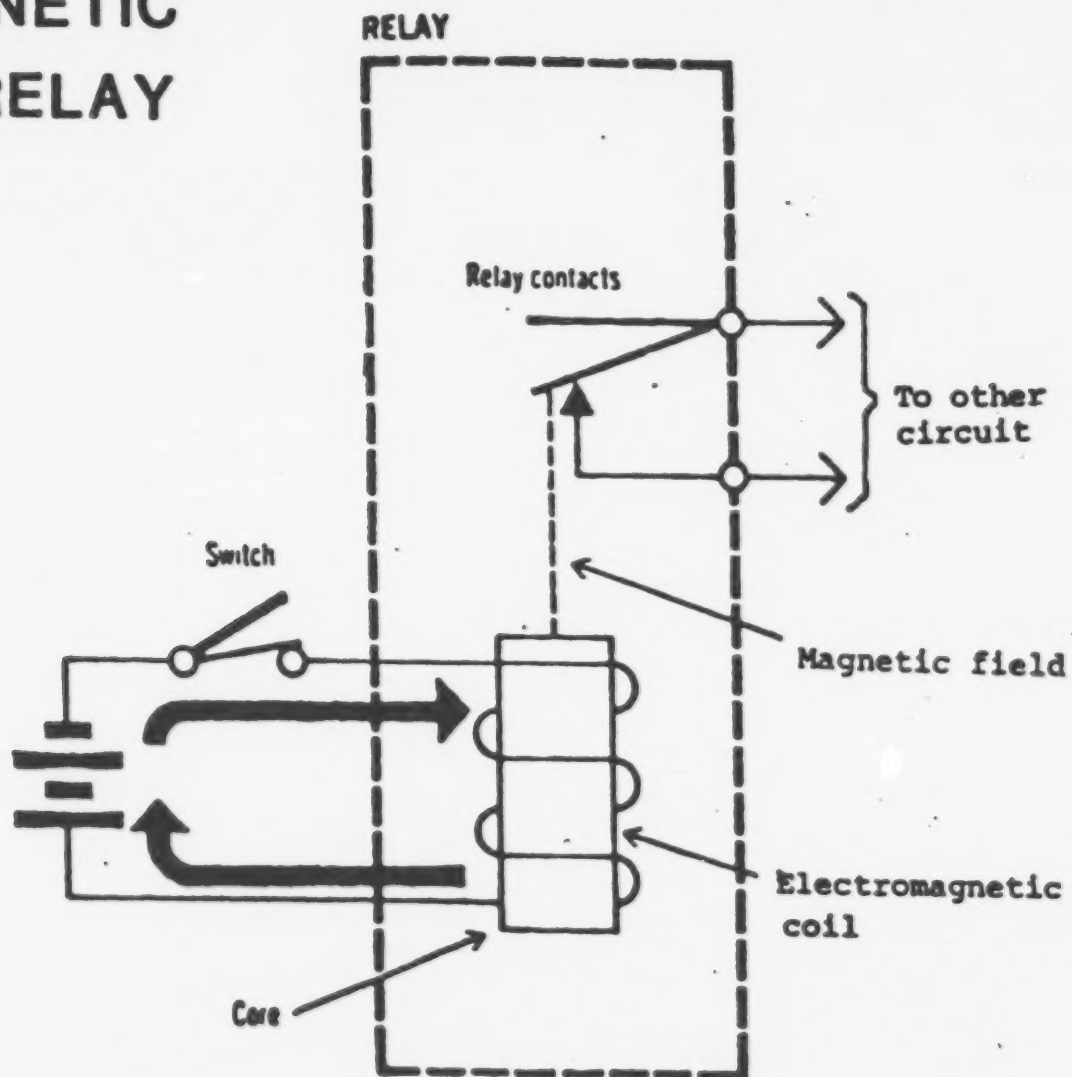
L = length in meters

ELECTROMAGNETIC RELAY

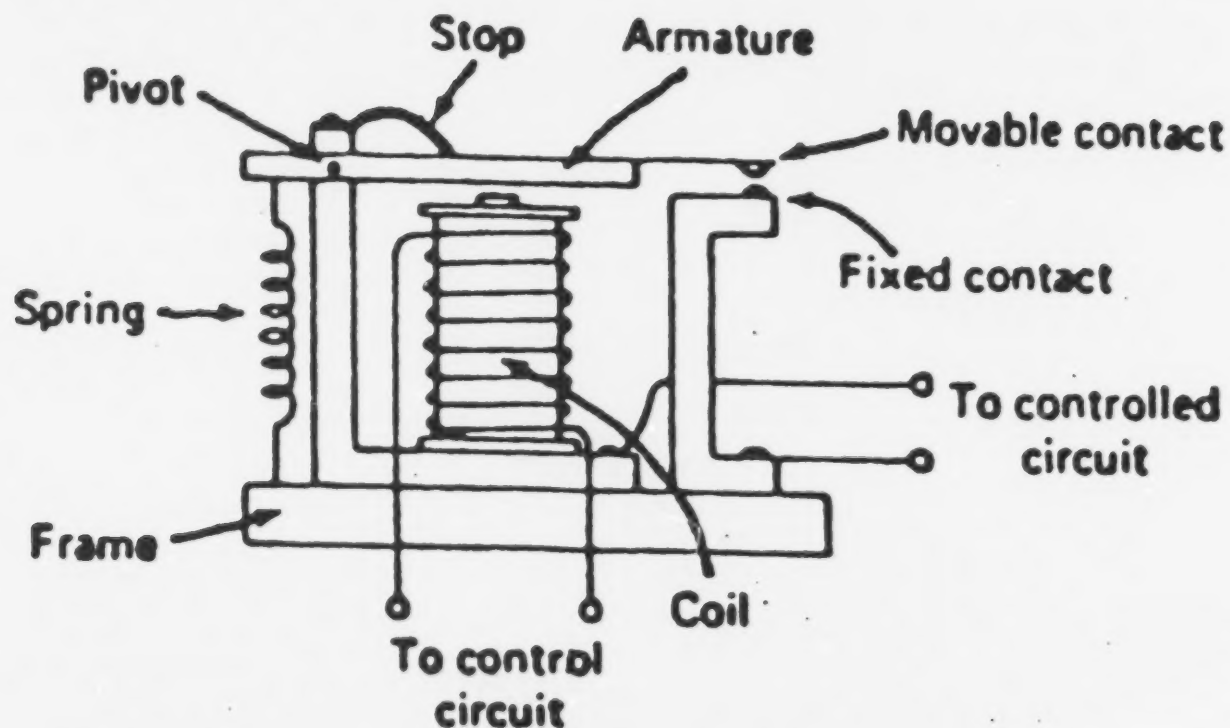




ELECTROMAGNETIC RELAY

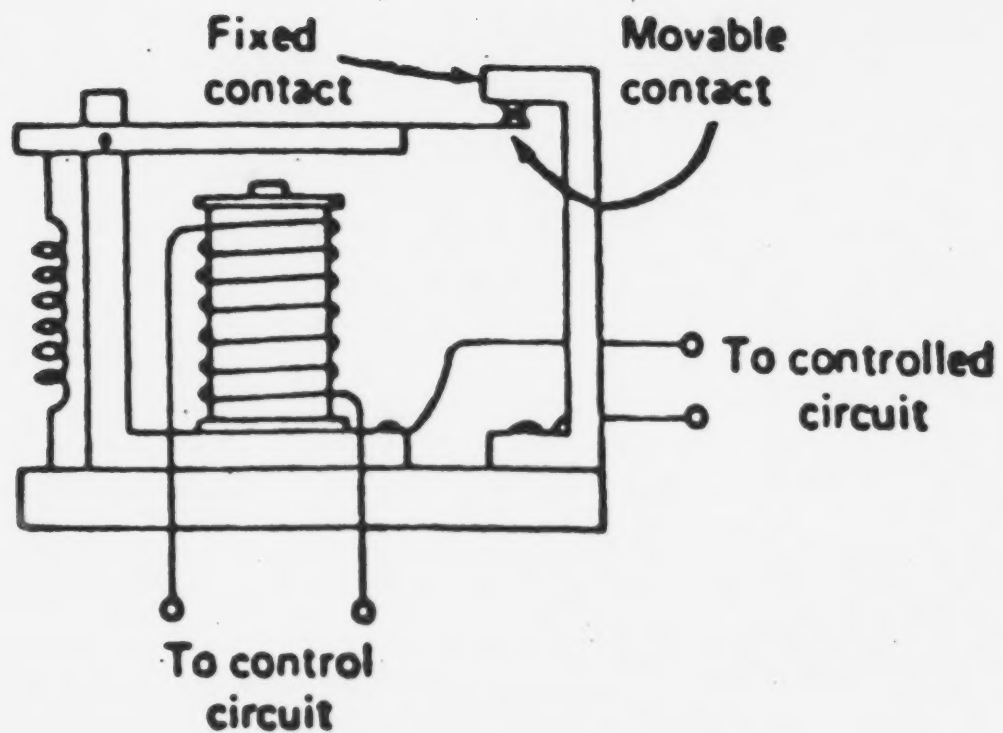


ELECTROMAGNETIC RELAY



NORMALLY OPEN RELAY

ELECTROMAGNETIC RELAY



NORMALLY CLOSED RELAY

Title: Electromagnet (Dinger)

Category: Systems

Description:

An electromagnet is a magnet made by sending electricity through a wire wound around a piece of iron. An electric current passing through the coil sets up a magnetic field which magnetizes the core. The iron core attracts iron. When the electric current is turned off the soft iron loses its magnetism rapidly. Electromagnets are used for many purposes and in all kinds of electrical apparatus. They have many applications wherever we have a magnetic field which can be varied such as lifting magnets, telephone receivers, motors and generators, radio loud-speakers, brakes for cranes and elevators and circuit breakers to name a few.

Math Concepts:

1. $I = \frac{E}{R}$

Amperes = $\frac{\text{volts}}{\text{resistance}}$

2. multiplication and division
with decimals
3. solving word problems
4. equations
5. completing tables
6. ratios

Title: Electromagnet (Dinger)

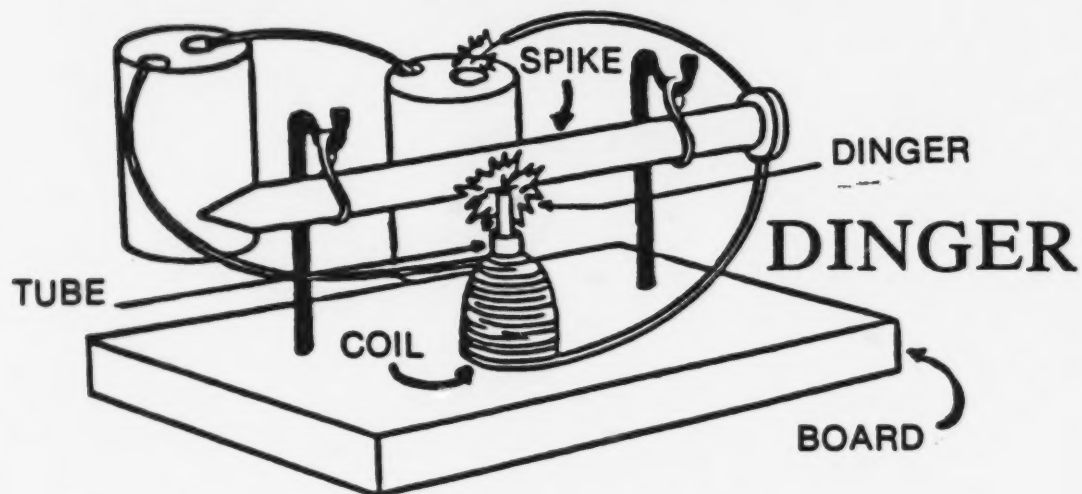
Category: Systems

Science Concepts:

1. Electricity is a kind of energy. Energy is anything that can make things work.
2. Electromagnets are used to change electricity into power (motion).
3. Electromagnets have many applications wherever we need a magnetic field which can be varied. The current produces a magnetic field.
4. When magnetism cannot further be increased, however great the current, a magnet is saturated.
5. Strength of an electromagnet depends on the number of turns in the coil, and on the strength of the current.
6. Current electricity is a steady flow of electricity through a wire.
7. Electricity can magnetize iron.
8. All magnetism is caused by charges in motion.
9. An electron is a tiny part of an atom. Electrons carry a small amount of electricity. Copper conductors of electricity are used in the wire to move electrons. Electrons flow from negative to positive seeking to level or "balance the charge."
10. Electrical pressure created by the cell is called the electromotive force.
11. Current produces a magnetic field
12. Ohm's Law-ratio of the potential difference to the current of the resistance of the circuit. The formula is written.

$$\text{Resistance} = \frac{\text{Potential difference}}{\text{Current}}$$

THE ELECTROMAGNET



MATH CONCEPTS

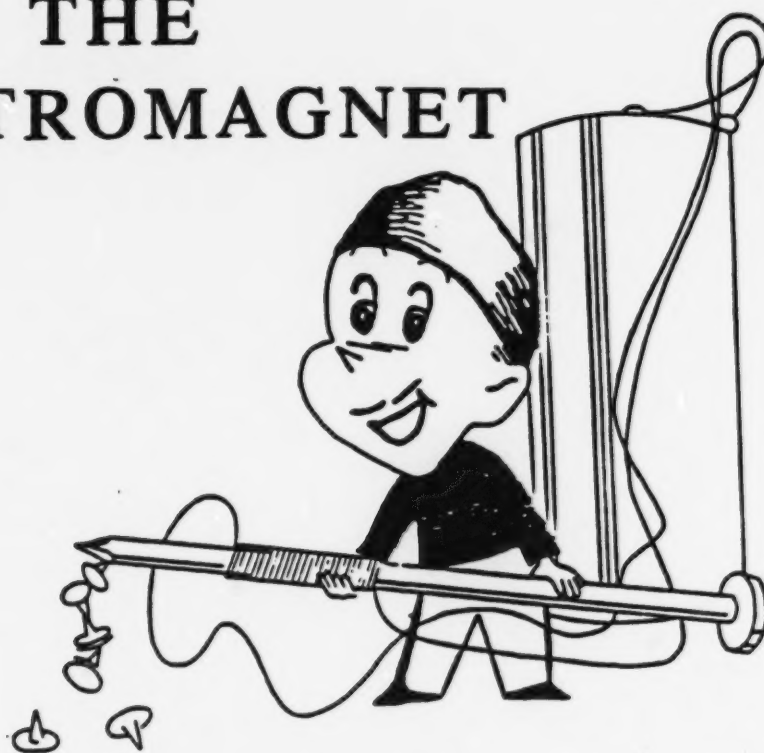
OHM'S LAW
 $R = E/I$

SCIENCE CONCEPTS

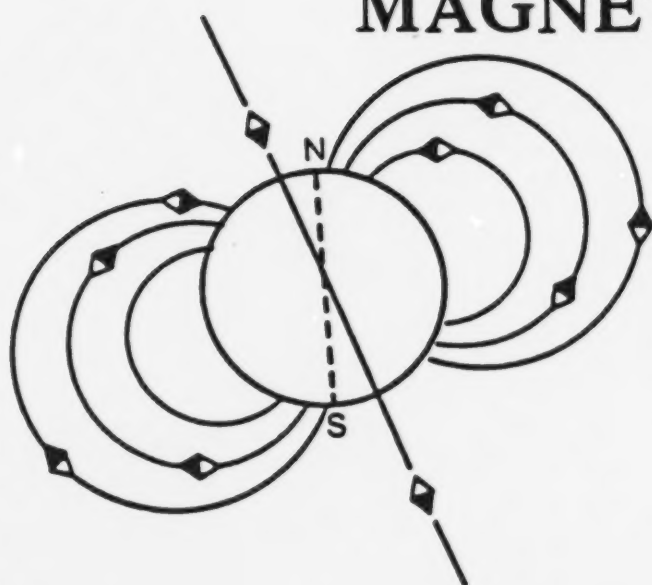
CURRENT CAUSES MAGNETIC
FIELD

ELECTROMOTIVE FORCE
CONDUCTOR

THE ELECTROMAGNET



MAGNETIC FIELD



Title: Electron Beam Deflection

Description: The electron beam's position on the screen of a CRT is controlled by electrostatic beam deflection. The effects that a charge placed on the deflection plate has on an electron beam is presented. A simplified diagram of a CRT is presented. The electrical and physical values in a CRT required to determine the amount of deflection are described. The related math formula used to calculate the distance of deflection on the screen is given.

Science Concepts:

1. Understanding beam formation.

Thomas Edison in the 1880's discovered that a heated wire would produce a current. This phenomenon became known as the Edison Effect and is the basic principle underlying the operation of any type of electronic tube.

In the CRT, as it is applied in the oscilloscope, an electrode known as a cathode is heated. The heat increases the velocity of the valence electrons to the point where they break free of the material's surface and are emitted by a process referred to as thermionic emission. Only substances considered to be good conductors are used for the cathode because they usually have only one valence electron that is easily energized to break it free from the atom. As the electrons are emitted they are attracted to the positive voltage applied to the electrode known as the anode.

2. Understanding the deflection of the electron beam.

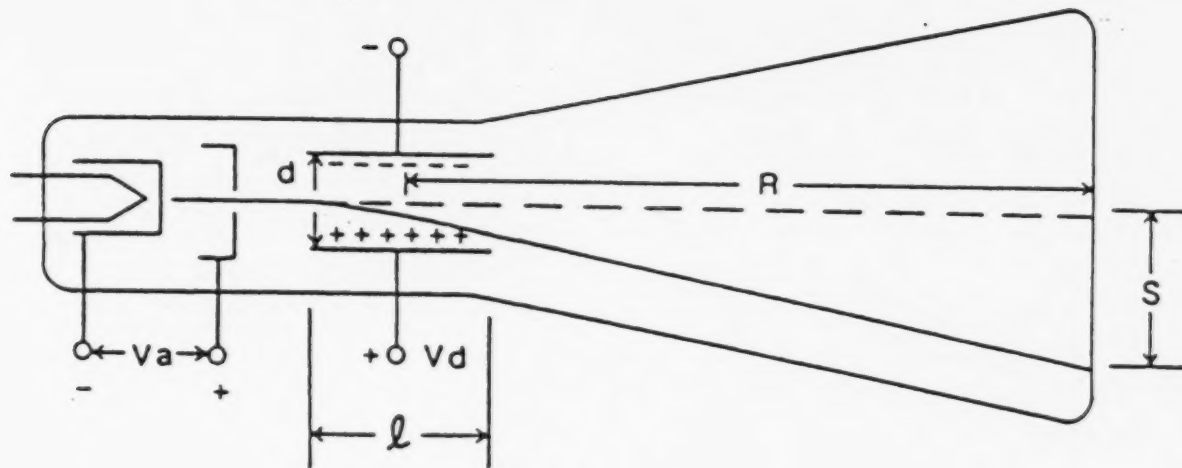
Once the electron beam is formed, it is accelerated, then guided within an electrostatic field so the beam can be directed to strike any point on the screen. A combination of influences by the horizontal and vertical deflecting fields causes the beam to produce a visible trace on the screen. The electron beam is deflected by two sets of plates set at right angles to each other. Charging the plates produces an electrostatic field which exerts a force on the negatively charged electron beam. The positive plates will attract the beam and the negative plates will repel the beam. Changing the charges will alter the direction of the beam.

MATH CONCEPTS;

1. Interpreting the formula $S = \frac{1}{2} \cdot \frac{V_d}{V_a} \cdot \frac{l}{d} \cdot R$ when S stands for deflection and is defined by the equation $\tan \phi = \frac{S}{R}$.
2. Understanding the trigonometric function ($\phi, \tan \phi$). Since ϕ is the angle through which the beam is deflected, $\tan$ gives us the deflection.
3. Using the formula $S = \frac{1}{2} \cdot \frac{V_d}{V_a} \cdot \frac{l}{d} \cdot R$ to determine the deflection voltage, the accelerating voltage, the distance between deflecting plates or the length of deflecting plates, given the values of the other variables.
4. Reading metric measurements.
5. Combining linear measurements and electrical measurements as it applies in the formulae.

ELECTRON BEAM DEFLECTION

CATHODE RAY TUBE



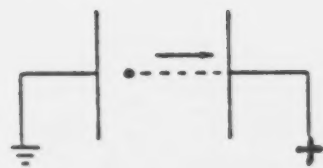
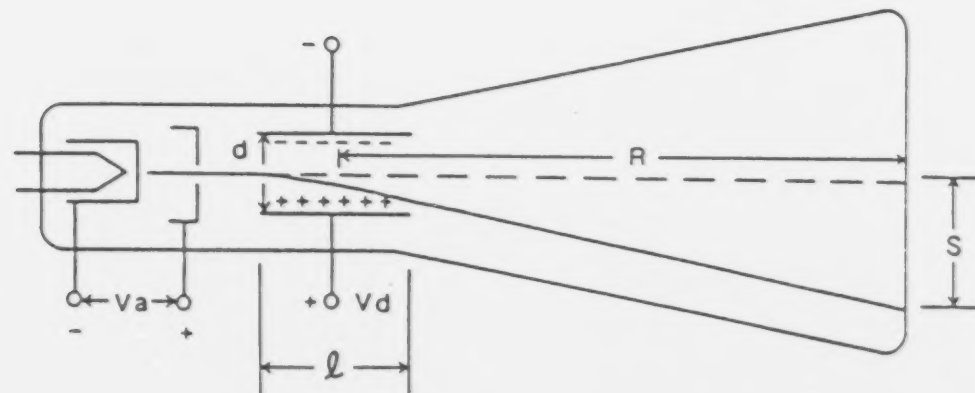
To Calculate Deflection:

$$S = \frac{1}{2} \cdot \frac{V_d}{V_a} \cdot \frac{l}{d} \cdot R$$

- S = Distance of Deflection
- V_a = Accelerating Voltage
- V_d = Deflecting Voltage
- d = Distance between plates
- l = Length of deflecting plates
- R = Distance from plate midpoint to screen

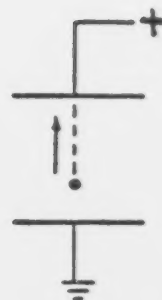
ELECTRON BEAM DEFLECTION

CATHODE RAY TUBE



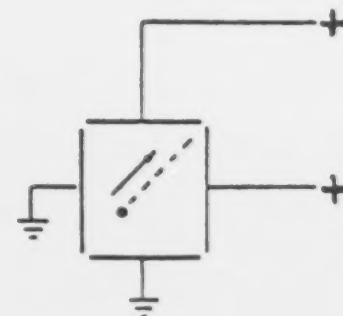
Horizontal
Deflection

PLUS



Vertical
Deflection

PRODUCES



Angular
Deflection

TITLE: THE ELECTRONIC MAZE GAME

CATEGORY: PROCESS

DESCRIPTION:

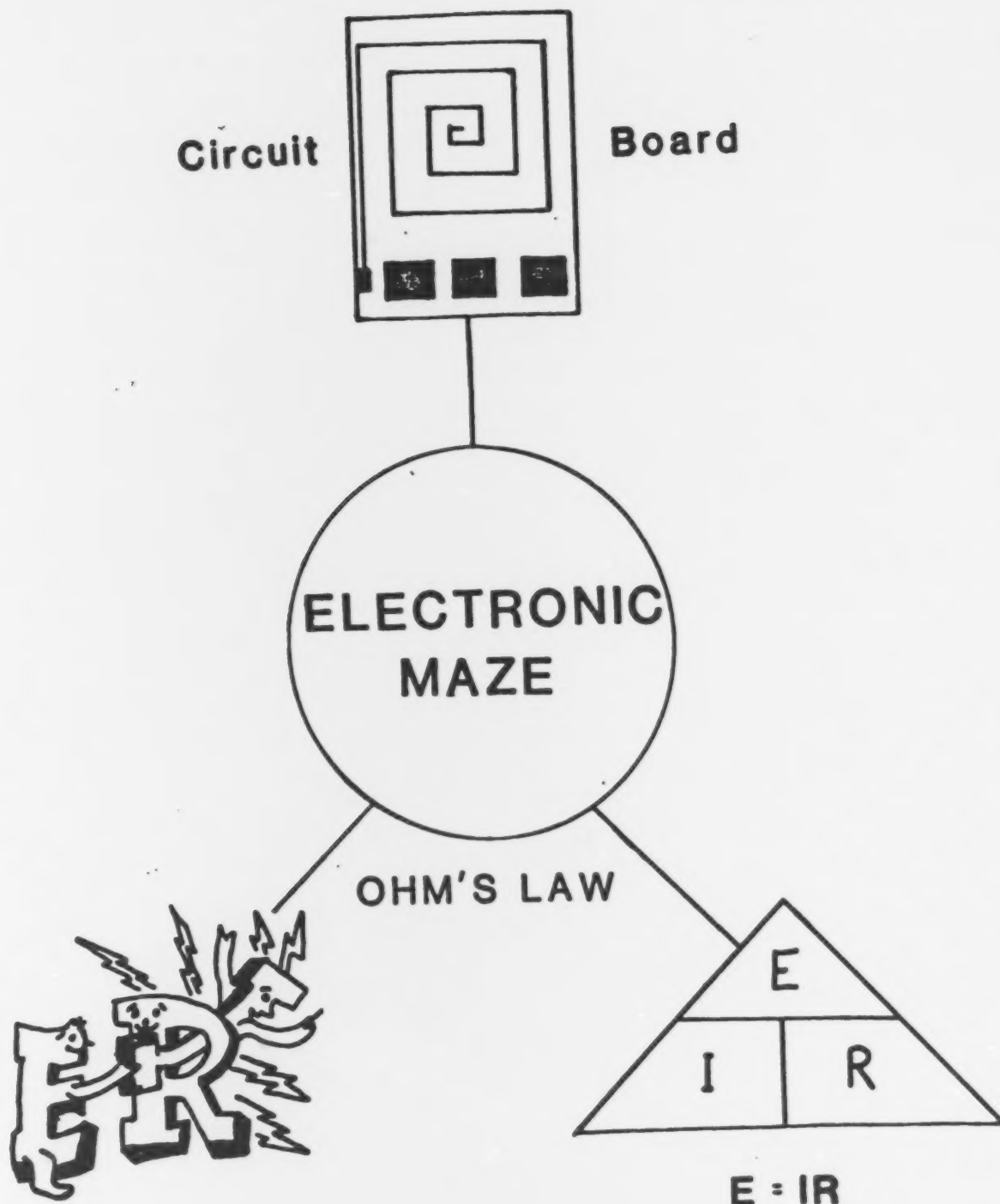
The electronic maze game is designed to provide the students with a game while introducing them to the field of electronics. During the construction of the project, the students will gain experience in measurement, layout and design, printed circuit boards, identification and description of electronic components, soldering and assembly techniques. While identifying and describing electronic components, the students will learn about voltage, current, and resistance, and the application of Ohm's Law.

SCIENCE CONCEPTS:

1. Electricity is the movement of electrons in a field of force.
2. The attraction and repulsion of charges is explained by unlike charges pulling together and like charges pushing apart.
3. Coulomb's Law (the law of electrical charges) states that the force of attraction or repulsion varies directly with the amount of charges and inversely with the square of the distance between them.
4. Ohm's Law explains the relationship among voltage, current, and resistance in an electrical circuit.

MATHEMATICAL CONCEPTS:

1. Multiplication of whole numbers
2. Division of whole numbers
3. Using a formula
Ohm's Law
 - a. Computing voltage $E=IR$
 - b. Computing current $I=\frac{E}{R}$
 - c. Computing resistance $R=\frac{E}{I}$
4. Proportion
 - a. Direct proportion
Current is directly proportional to voltage
 - b. Inverse proportion
Current is inversely proportional to resistance



ONE VOLT IS REQUIRED TO PUSH
ONE AMP THROUGH ONE OHM RESISTANCE

Title: Flyball Governor

Category: Innovation

Description:

Most steam engines are required to run at a constant speed even though the load on the engine is variable. A governor has the ability to vary the engine speed under a variety of load conditions. The Flyball governor is the most popular type of governor. It consists of two or more balls mounted on a rotating shaft. The rotating shaft is attached to the engine and responds to the engine speed so the balls move up and out as the engine increases speed. This causes the governor to let in more or less steam to maintain, as closely as possible, a constant engine speed.

Science Concepts:

It is the inertia of objects that causes centrifugal force.

According to Newton's First Law of Motion every body in motion tends to stay in motion in a straight line unless an outside force acts on it. Since objects moving in a circle are obviously not going in a straight line, there must be a force acting on them. That force is the centrifugal force.

Title: Flyball Governor

Category: Innovation

Science Concepts:

Definitions:

1. Centrifugal Force - A force that tends to cause rotating objects to move apart.
2. Centripetal Force - A force that pulls toward the center of an object.
3. Class Two Lever - Lever in which the energy is applied to one end, the fulcum is at the other end, and the load is in the middle.
4. Fulcrum - The rotation point in a lever.
5. Gravity - A force that pulls all objects toward the center of the earth, or any other body.
6. Inertia - The resistance of an object to changes of motion.

Principles:

1. The governor is attached to the engine by a pulley in such a way that it spins at a speed proportional to the speed of the engine.
2. As engine speed increases the weights' move outward from the center of the governor due to centrifugal force.
3. As the weights move outward, a class two lever attached to the weight lifts the counterpoise which in turn activates a control device to reduce the amount of energy (steam, etc.) running the engine causing the engine to slow down.
4. As the engine speed slows, the counterpoise is pulled down by gravity and centripetal force pulls the weights into a smaller circle which activates a control device to increase the amount of energy (steam, etc.) running the engine causing the engine to speed up.

Title: Flyball Governor

Category: Innovation

Math Concepts:

1. Centrifugal Force

The strength of this force can be quantified. In this way we can study the relationship between speed (or velocity) and the radius of the path of an object. Consider the formula:

$$C = \frac{W \times V^2}{G \times R} \quad \text{where } C = \text{Centrifugal force}$$

W = Weight of an object

V = Velocity of an object

G = Acceleration caused by gravity

R = Radius of object's path

If we keep the weight and the gravitational pull constant, what happens to the speed as we increase the size of the circular path? Since R is in the denominator of the ratio, as it increases, the value of C decreases, as does the speed. V in this formula is not only in the numerator but it is squared. Therefore, any increase in the speed dramatically diminishes the radius of the object's path.

2. Circumference of Circles

The Flyball governor operates on a drive pulley as does the engine which it is controlling. These pulleys are cylindrical in shape, so the path of the belts which go around them is circular. If both pulleys have the same diameter, the speed of the governor will equal the speed of the engine. If we increase the size of one pulley its speed decreases. Both pulleys would have travelled the same linear distance, but the smaller one would have to make more revolutions to achieve the same distance. It is helpful to realize that the circumference, pi times the diameter, is a linear measure.

Title: Flyball Governor

Category: Innovation

Math Concepts:

3. Ratio and Proportion

The relationship between the size of the two aforementioned pulleys is proportionate to their speeds. Assign the following variables:

C_1 = Circumference of the engine pulley

C_2 = Circumference of the governor pulley

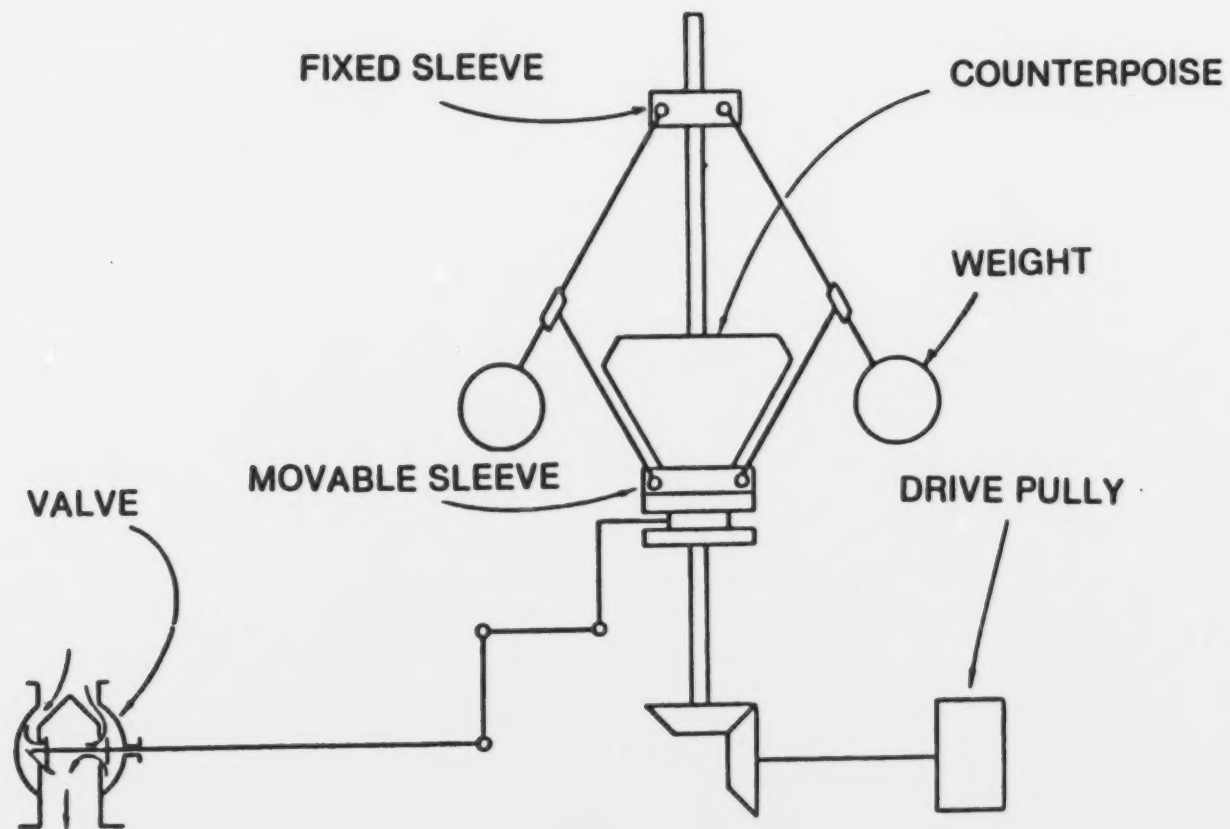
S_1 = Speed of engine

S_2 = Speed of governor

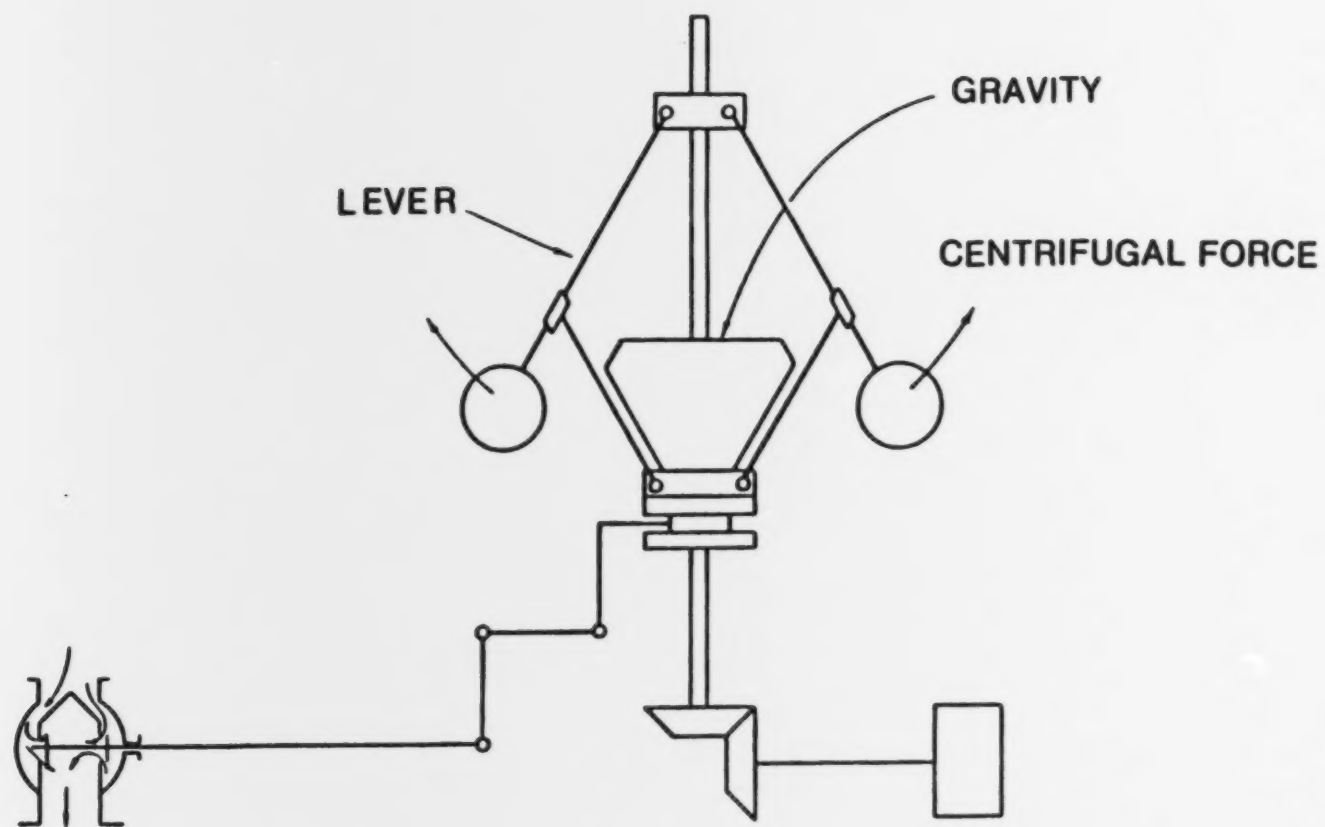
We can now express the proportion symbolically as: $\frac{C_1}{C_2} = \frac{S_1}{S_2}$

Changing the size of either cylinder establishes a new ratio between pulleys. This same ratio will apply to the comparative speeds of the pulleys. Thus the proportion between pulley sizes and their speeds is maintained. The speed of the governor relative to that of the engine is determined by the diameters of the governor pulley and the engine pulley.

FLYBALL GOVERNOR



FLYBALL GOVERNOR



TITLE: FOUR STROKE ENGINE

CATEGORY: INNOVATION

DESCRIPTION:

There are several advantages in using a four cycle engine. Some of the characteristics are: the intake, compression, power, and exhaust strokes are separate making the four cycle engine more fuel efficient. This greater combustion efficiency results in less pollution. The four cycle engine has a greater life expectancy, because oil is pumped throughout the entire engine providing consistent lubrication.

SCIENCE CONCEPTS:

1. Combustion occurs when a substance combines with oxygen to produce an explosion resulting in heat energy.
2. The volume of a gas increases as its temperature increases if the pressure remains constant--Charles' Law.
3. The volume of a gas decreases as the pressure on it increases if the temperature remains constant--Boyle's Law.
4. The higher the compression the more powerful the force of combustion.
5. A gas moves from a high pressure area to a low pressure area to equalize pressure--Bernoulli Principle.
6. Pressure--one pascal equals 1 newton of pressure per square inch (6.5 square centimeters).
7. Atmospheric pressure is a pressure pushing down on everything. This pressure is 100 kilopascals per square inch (6.5 square centimeters).

MATHEMATICAL CONCEPTS:

$$\text{Horsepower} = \frac{\text{Distance (meters)} \times \text{Force (newtons)}}{\text{Time (min.)} \times 33.00}$$

$$\begin{aligned}\text{Engine Displacement } V &= \pi \times r^2 \times h \\ &= 3.14 \\ r &= \frac{1}{2} \text{ the bore diameter} \\ h &= \text{stroke length}\end{aligned}$$

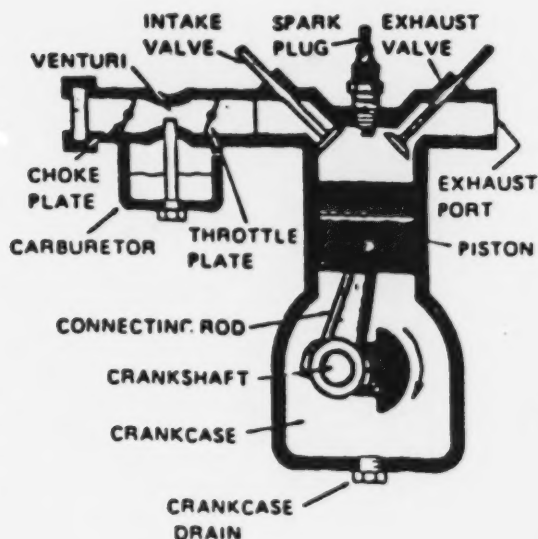
Stroke = distance from TDC (Top Dead Center) to the piston at ADC (Bottom Dead Center)

Bore = distance across the cylinders

Torque = Force x Radius

$$\text{Power} = \frac{\text{Distance} \times \text{Force}}{\text{Time (minutes)}}$$

FOUR-CYCLE ENGINE



SCIENCE CONCEPTS

CHARLE'S LAW

BOYLE'S LAW

BERNOULLI PRINCIPLE

AIR PRESSURE

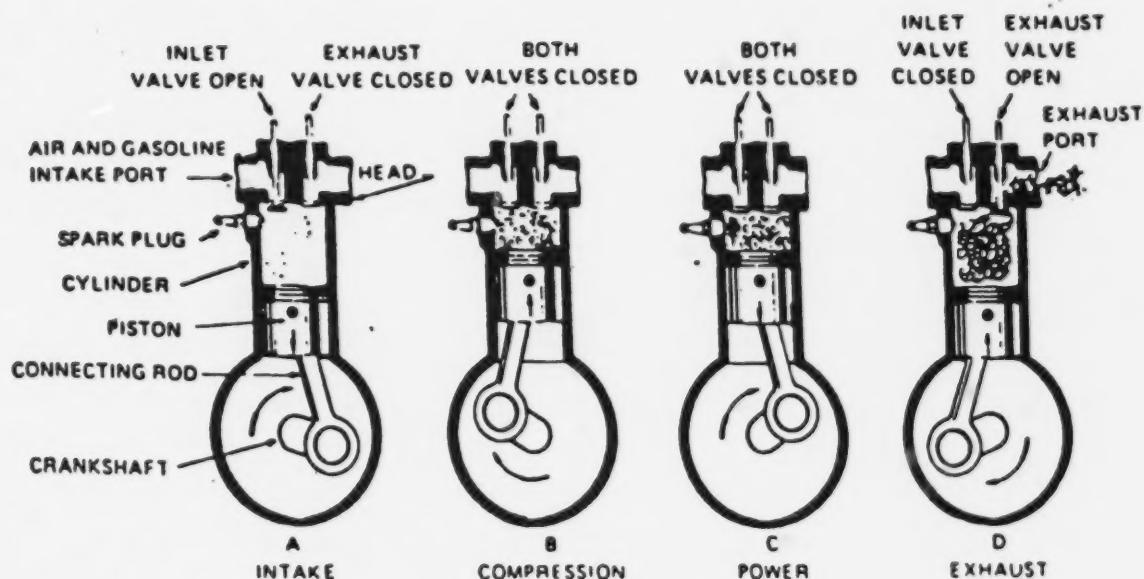
COMPRESSION

MATH CONCEPTS

$$\text{H.P.} = \frac{\text{DISTANCE} \times \text{FORCE}}{\text{TIME} \times 33.00}$$

$$\text{POWER} = \frac{\text{DISTANCE} \times \text{FORCE}}{\text{TIME}}$$

$$\text{TORQUE} = \text{FORCE} \times \text{RADIUS}$$



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Title: Full-Wave Rectification

Category: System

Description:

A full-wave rectifier circuit takes alternating current and changes the positive and negative portion of the sine-wave to pulsating direct current at twice the frequency of the half-wave rectifier circuit.

The increase in the frequency is very important in delivering voltage to complex electronic devices and circuits.

Science Concepts:

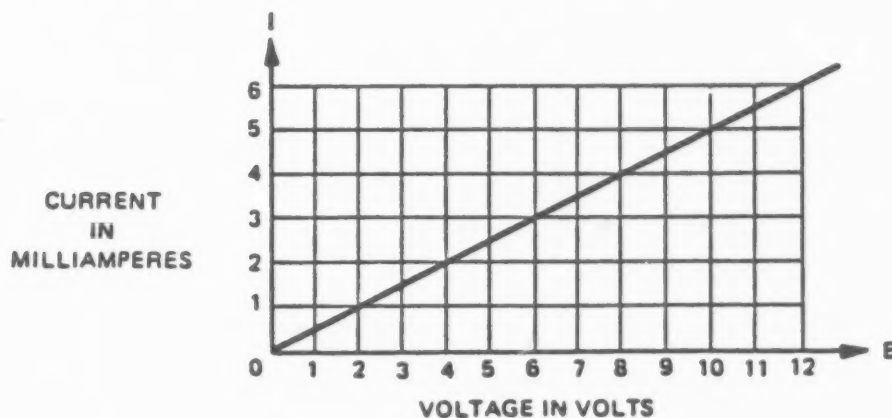
1. Full-wave rectification results in current flowing in the circuit for both positive and negative cycles of the AC input.
2. Full-wave rectified current results in an average value twice that of a half-wave rectified current and uniform output.
3. A transformer can be used to make a full-wave rectifier circuit.
4. The center tap transformer is connected to the ground which will be zero volts at all times.
5. Electron theory of current flow.
6. Sine-wave shows the relationship of ac voltage to ac current in a circuit.
7. Polarity resulting in forward bias and reverse bias.
8. N-Type and P-Type semiconductors.
9. Good conduction is from N-Type material to P-Type.
10. PN junction diode will conduct well in one direction.
11. Magnetism and the magnetic lines of force.
12. Electromagnetism used to generate electrical power by rotating a coil of wire in a magnetic field.
13. Mechanical energy is required to produce electrical power.
14. Maintaining electron flow in a circuit is dependent upon maintaining an excess of free electrons at the negative pole of the circuit and a deficiency of free electrons at the positive pole.

Title: Full-Wave Rectification

Category: System

Mathematical Concepts:

- (1) Add, subtract, multiply and divide rational numbers
- (2) Evaluate an algebraic expression given the value of its variables
- (3) Transform a formula to express a particular variable in terms of other variables
- (4) Graph ordered pairs and locate points on a graph
- (5) Apply the use of graphs to electronics
 - (a) This graph demonstrates how a fixed resistance of 2000 ohms reacts as different voltages are applied. Use this graph for the following problems.



- (b) What current exists with an applied voltage of 4v?
- (c) Using Ohm's Law, calculate the value of the resistance for each applied voltage. $R = E / I$ 4v 8v and 12V
- (d) Power law formula, calculate the power consumed for each applied voltage $P = I \times E$ 60v and 10v.

Title: Full-Wave Rectification

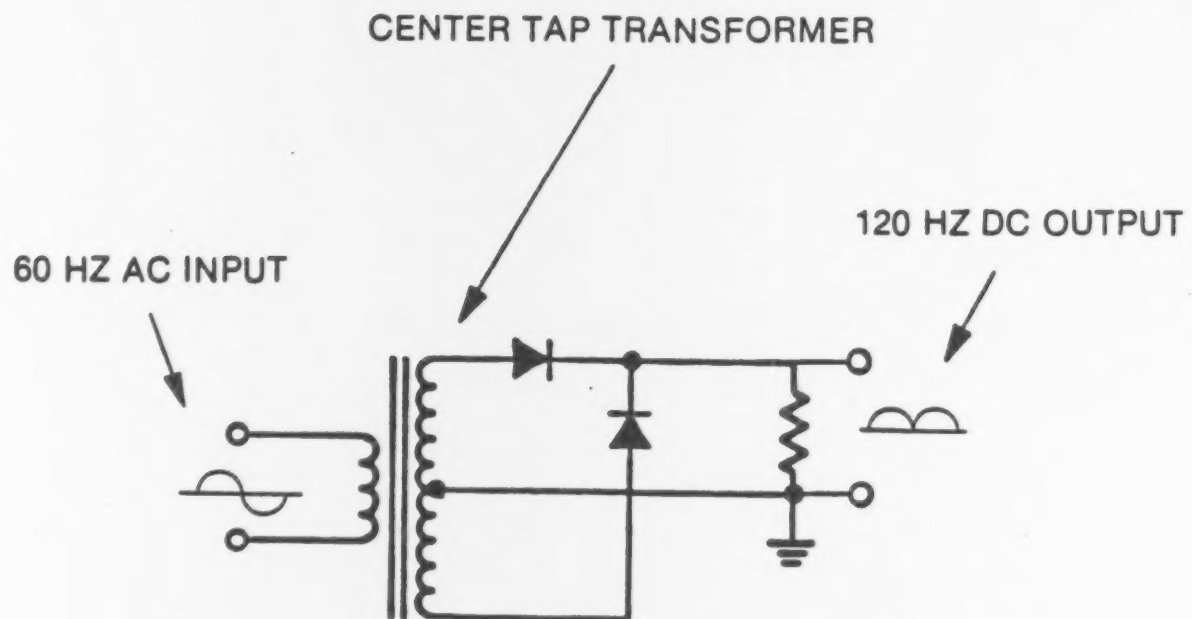
Category: System

Mathematical Concepts:

- (e) Notice that as the applied voltage increases the current also increases.
- (6) Construct graphs of the Trigonometric Function.
- (7) Construct a vector diagram and freehand the sine wave and indicate the voltage or current in both vector and wave diagram.
- (8) Formula $V_{av} = V_{RMS} \times 0.9$ for calculating the average dc voltage in a full wave rectifier circuit.

Frequency = $\frac{1}{\text{time base}}$ formula for finding the frequency
with an oscilloscope

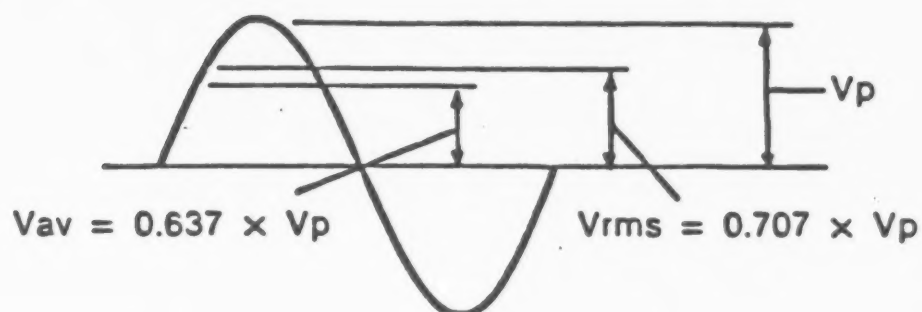
FULL-WAVE RECTIFICATION



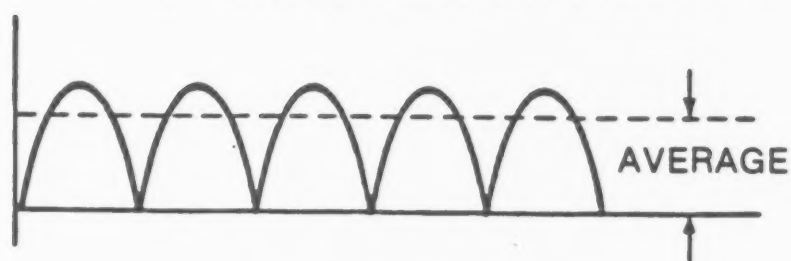
$$F_o = \frac{1}{\text{TIME BASE}}$$

FULL-WAVE RECTIFICATION

AC SINE-WAVE INPUT



DC WAVE-FORM OUTPUT

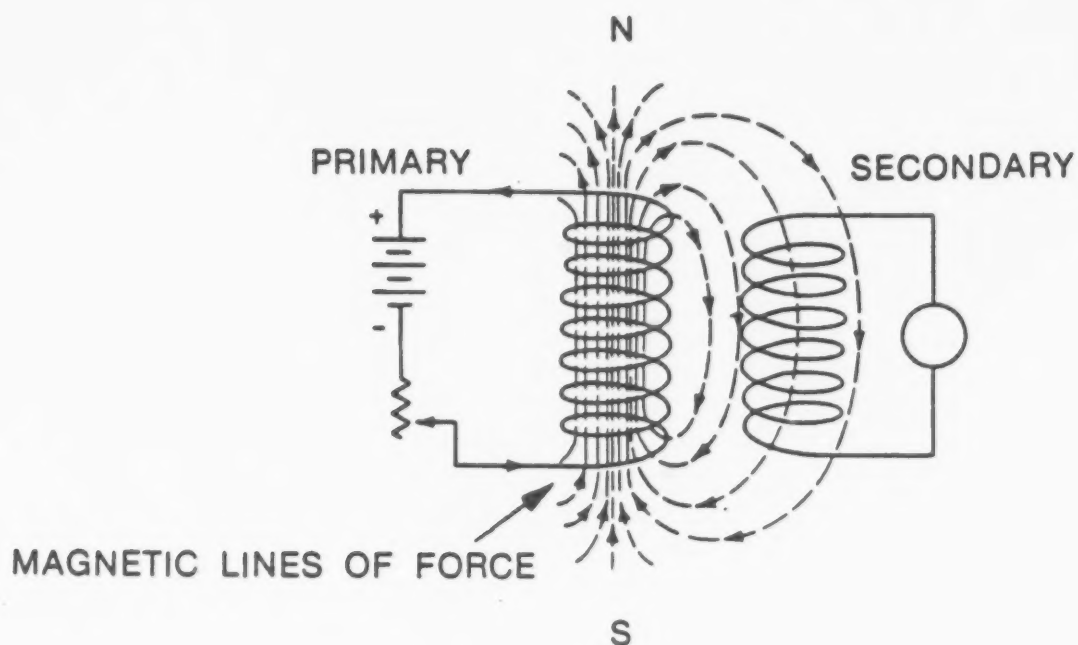


FULL-WAVE DC

$$V_{av} = V_{rms} \times 0.9$$

FULL-WAVE RECTIFICATION TRANSFORMER

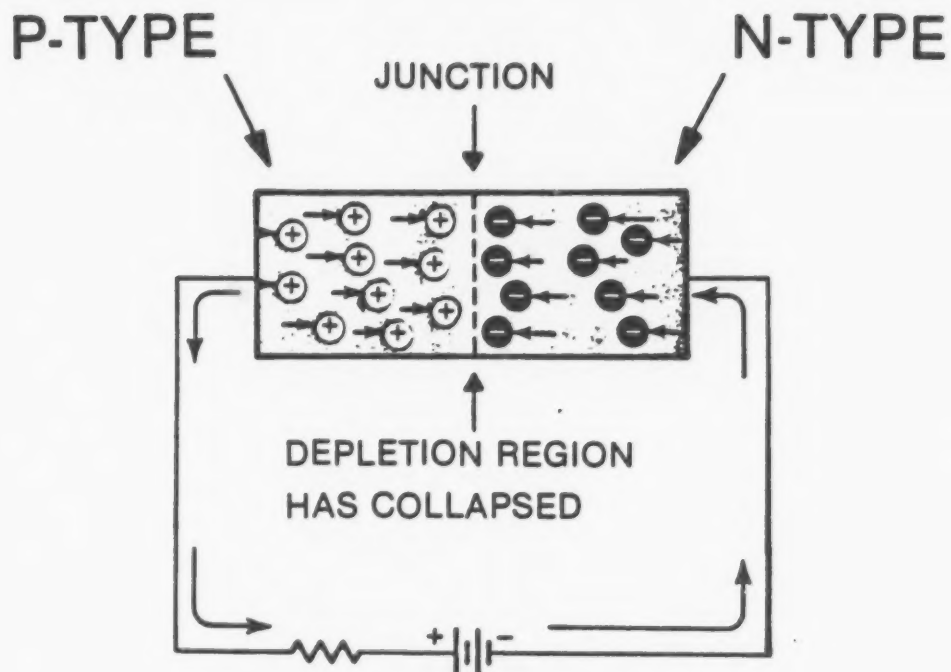
THE MAGNETIC LINES SPREAD OUTWARD ACROSS THE
SECONDARY COIL AND AN ELECTRO-MOTIVE FORCE IS
INDUCED IN THE SECONDARY CIRCUIT.



$$\frac{E_p = I_s = N_p}{E_s = I_p = N_s}$$

FULL-WAVE RECTIFICATION

DIODE RECTIFIER



FORWARD BIAS

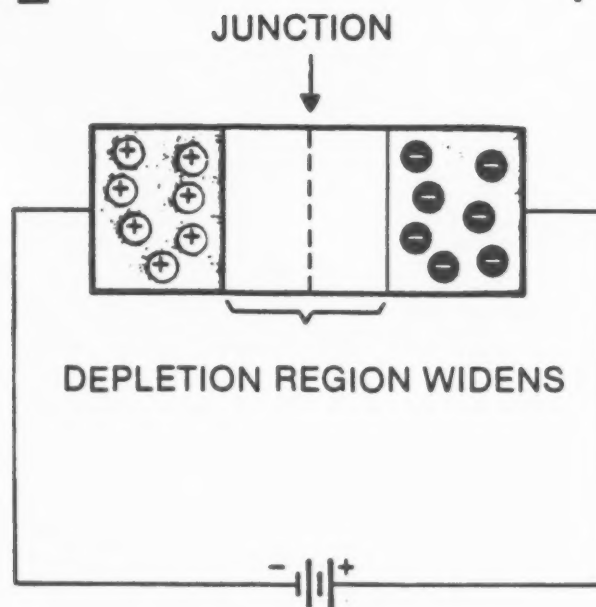
BATTERY POLARITY REPELS P-TYPE AND N-TYPE SILICON CAUSING THEM TO ATTRACT EACH OTHER AND PRODUCING CURRENT FLOW ACROSS THE DEPLETION REGION.

FULL-WAVE RECTIFICATION

DIODE RECTIFIER

P-TYPE

N-TYPE



REVERSE BIAS

BATTERY POLARITY IS REVERSED CAUSING LIKE CHARGES TO ATTRACT. THIS PROCESS WIDENS THE DEPLETION REGION AND CURRENT CAN NOT FLOW.

TITLE: GEARS

CATEGORY: INNOVATION

DESCRIPTION:

A gear is a wheel with teeth along its rim. It changes the strength or direction of a force. Forces are simply pushes and pulls. A force is needed to start a bike moving. Your feet exert a force on the pedals, causing the chain to exert a force on the axle of the back wheel.

SCIENCE CONCEPTS:

1. Gears are toothed wheels used to transmit power between components of a machine.
2. Gears are used to drive a second part or the mechanism in either the same or the opposite direction to that of the motion or other driving force.
3. The most important single use of gears is to transmit motion from a power source.
4. Motion can be transmitted from one smooth-surfaced cylinder to another by friction.
5. Friction is a force that acts against the motion of another force.
6. Force is any push or pull.
7. Friction is caused by cohesion, or the attraction of like molecules of the same materials or by adhesion, or the attraction of unlike molecules in two different surfaces.
8. The friction of moving parts in a machine reduces the mechanical advantage of the device.
9. The mechanical advantage of speed and force can be changed.
10. Mechanical advantage is the number of times a machine multiplies the effort.

TITLE: GEARS

CATEGORY: INNOVATION

MATHEMATICAL CONCEPTS:

1. In an inverse proportion there is a decrease in the first quantity as the other quantity increases.
2. Speed is inversely proportional to time over a constant distance. (If we increase the speed, we decrease the time.)
3. When two gears are meshed, the revolutions per minute (rpm) are inversely proportional to the number of teeth. (If you increase the number of teeth on one gear, you decrease its rpm.)
4. To establish an inverse proportion, we set a first-quantity ratio equal to the reciprocal (inverse) of a second-quantity ratio.

Example: The large gear is turning at 64 rpm. How many rpm is the small gear turning?

Since this is an inverse proportion, we set up the two ratios:

$$\frac{\text{rpm of large gear}}{\text{rpm of small gear}} = \frac{\text{no. of teeth on large gear}}{\text{no. of teeth on small gear}}$$

Now, the inverse proportion is

$$\frac{\text{rpm of large gear}}{\text{rpm of small gear}} = \frac{\text{no. of teeth on small gear}}{\text{no. of teeth on large gear}}$$

(Notice that the second ratio has been "flipped" to form its reciprocal.)
The large gear has 24 teeth and the small gear has 12 teeth, giving us the proportion

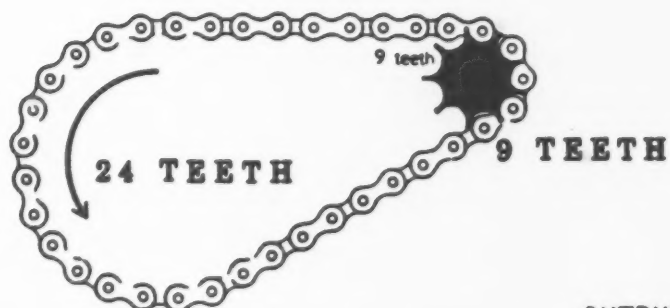
$$\frac{64}{n} = \frac{12}{24}$$

Simplifying the ratio on the right, we have

$$\frac{64}{n} = \frac{1}{2} \quad (\text{cross multiply and solve})$$

$$n=128$$

Gears



◀How the gears of a bicycle work. The larger chainwheel is the driver. The smaller ones (the sprockets) are fixed to the rear wheel and are driven. One turn of the chainwheel gives four turns of the rear wheel in top gear, three turns in mid gear and only two turns in low gear. Therefore the low gear is helpful when climbing hills, whereas high gear is best on level ground.

$$\text{OUTPUT SPEED} = \frac{\text{INPUT SPEED} \times \text{INPUT TEETH}}{\text{OUTPUT TEETH}}$$

Title: Half-wave Rectification

Category: System

Description:

Half-wave Rectifier Circuits change house current (alternating current) to DC (direct current), which is necessary to power all solid state equipment used today. DC does the same amount of work as AC but at lower voltage levels, which save energy.

Semi-conductor materials, such as diodes, transistors, small, medium, and large scale integrated circuits (SSI, MSI, LSI), have revolutioned today's society in both commercial and consumer markets.

Title: Half-wave Rectification

Category: System

Science Concepts:

1. Energy is the ability to do work.
2. Potential energy is possessed by electrons when they repel or push one another to a new position in a conductor.
3. Kinetic energy is associated with the actual movement of the electrons.
4. An electric current may be produced by the use of magnets.
5. Like magnetic poles always repel and unlike magnetic poles always attract each other.
6. The kinds of electrical power include alternating current or AC and direct current or d c.
7. Direct current occurs when electrons in a circuit flow in one direction.
8. Alternating current occurs when electrons flow in a back and forth motion at periodic intervals.
9. Mechanical movement between a magnet and a coil of wire results in the generation of electrical energy.
10. Magnetism is an invisible force on certain materials which enables attraction.
11. Electromagnetism combines electricity and magnetism.
12. Transformers are used to step up or step down a voltage.
13. Transformers consist of two coils located near each other.
14. The schematic diagram show primary and secondary windings and loops that represent turns of wire in the transformer.
15. Power is applied to one of the coils, called primary. Power is taken away from the other coil, called the secondary.
16. Step-down transformers have less turns on the secondary coil producing less secondary voltage.

Title: Half-wave Rectification

Category: System

Science Concepts:

17. Rectifiers are components that convert AC output voltage to dc output voltage.
18. A half-wave rectifier causes the average value of the current and voltage across the load to be low.
19. A half-wave rectifier allows current to conduct through a load for only one-half of each input cycle.
20. Law of conservation of matter and energy.
21. Electron structure and valence electrons.
22. Electron Bonding - ionic and covalent bonding.
23. Semiconductors do not allow current to flow easily.
24. Diodes are usually made of semiconductor material.
25. Diodes are useful in changing alternating current to direct current.
26. The diode has a continuous crystalline structure where electrons move across the junction.
27. N-Type semiconductor have free electrons which carry negative charge.
28. P-Type semiconductor have missing electrons which form holes and are assigned a positive charge.
29. PN junction diode will conduct well in one direction.
30. The process of doping materials to change its electrical characteristics.
31. Battery polarity in resulting in forward bias and reverse bias.

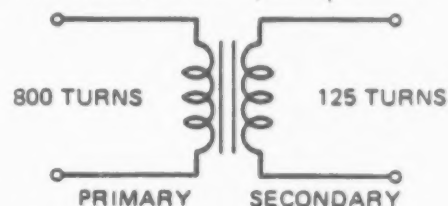
Title: Half-wave Rectification

Category: System

Mathematical Concepts:

1. Review and apply the principle multiplication and division of fractions and decimals.
2. Compare numbers as Ratio and Reduce them to lowest form as fractions or decimals.
3. Given a verbal statement containing a ratio, write the ratio in numerical form.

a) Find the ratio of primary turns to secondary turns in this transform diagram.



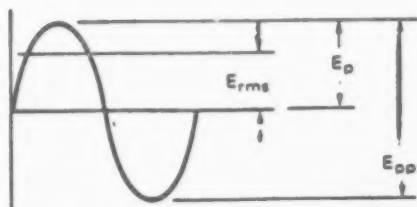
4. Solve a proportion with one unknown.
5. Write a proportion to solve a problem in electronic

a) Formula $\frac{E_p}{E_s} = \frac{I_s}{I_p}$

The voltage on the coil of a transformer is indirectly proportional to the current of the coil.

Where E_p = voltage of primary coil
 E_s = voltage of secondary coil
 I_p = current of primary coil
 I_s = current of secondary coil

6. Simplifying square roots.
7. Construct the graph of the sine function.

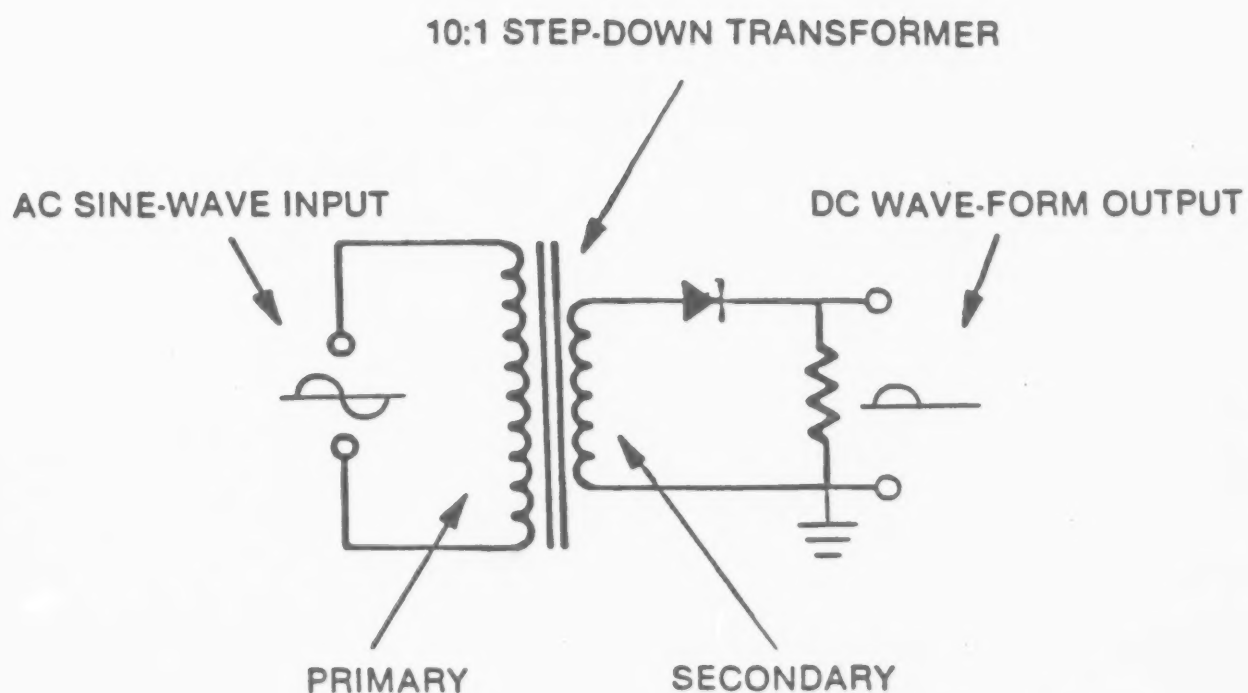


where E_{rms} = rms voltage

E_p = peak voltage

E_{pp} = peak-to-peak voltage

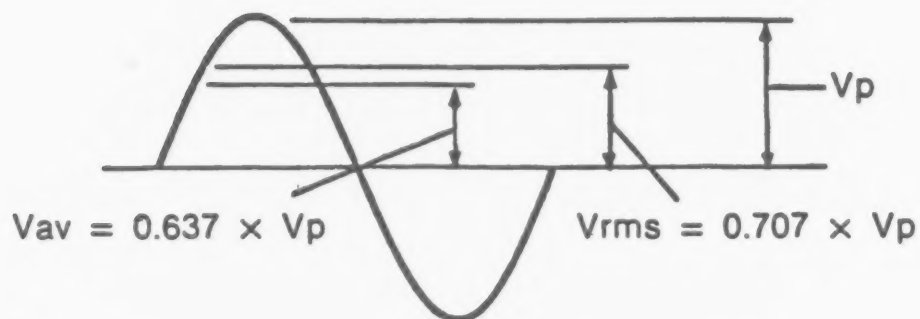
HALF-WAVE RECTIFICATION



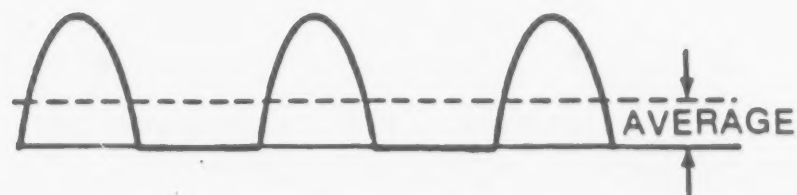
$$V_{\text{SECONDARY}} = V_{\text{PRIMARY}} \div \text{TRANSFORMER RATIO}$$

HALF-WAVE RECTIFICATION

AC SINE-WAVE INPUT



DC WAVE-FORM OUTPUT

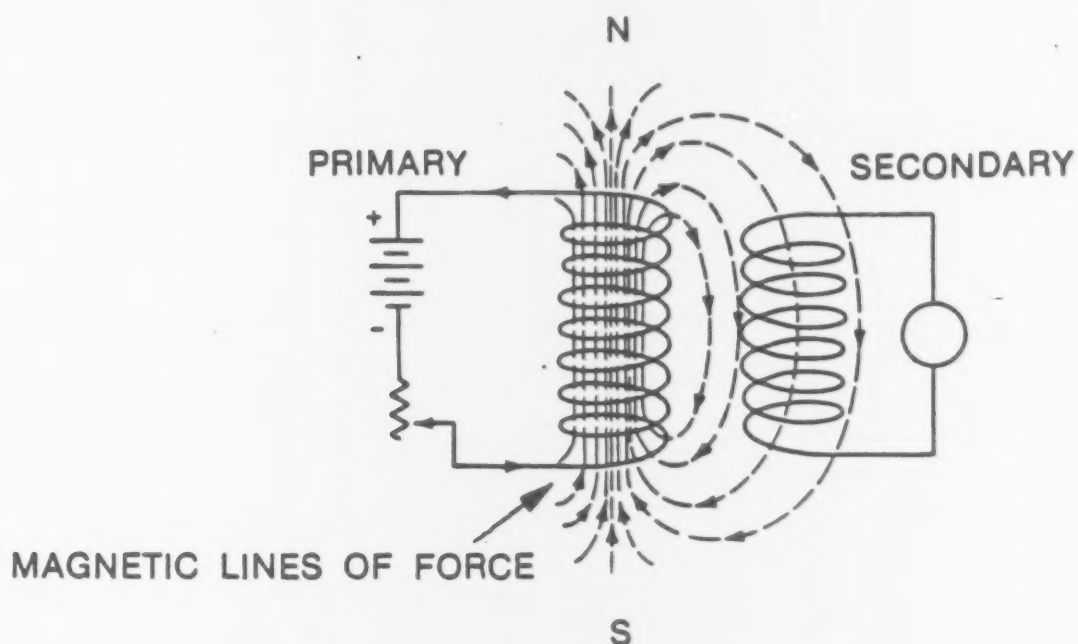


HALF-WAVE DC

$$V_{av} = V_{rms} \times 0.45$$

HALF-WAVE RECTIFICATION TRANSFORMER

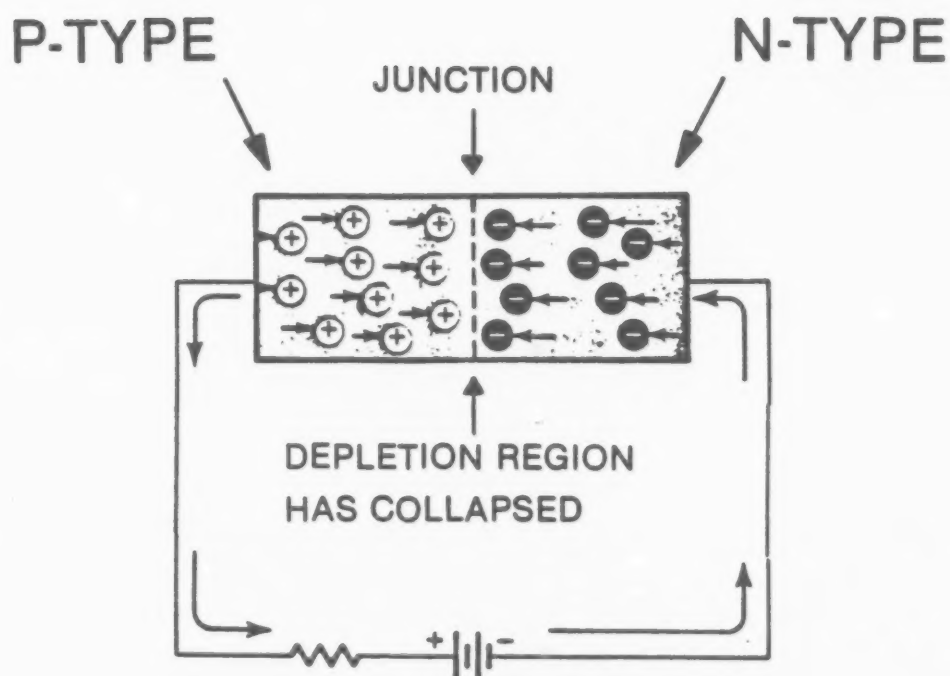
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$$\frac{E_p = I_s = N_p}{E_s = I_p = N_s}$$

HALF-WAVE RECTIFICATION

DIODE RECTIFIER



FORWARD BIAS

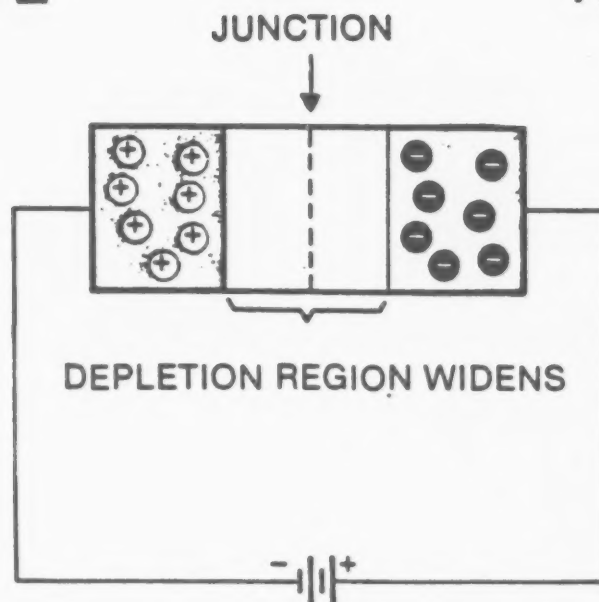
BATTERY POLARITY REPELS P-TYPE AND N-TYPE SILICON CAUSING THEM TO ATTRACT EACH OTHER AND PRODUCING CURRENT FLOW ACROSS THE DEPLETION REGION.

HALF-WAVE RECTIFICATION

DIODE RECTIFIER

P-TYPE

N-TYPE



REVERSE BIAS

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TITLE: HYDRAULICS--BRAKE APPLICATION

CATEGORY: SYSTEMS

DESCRIPTION:

Hydraulics is the study of liquids, usually oil, under pressure. It has been incorporated into many operating power transmitting systems such as automobile brakes. In the automobile, for example, the driver's force on the brake pedal is transmitted to the brakes on all four wheels without any direct mechanical connection. Hydraulic systems, such as this, have replaced or are part of many mechanical systems.

SCIENCE CONCEPTS:

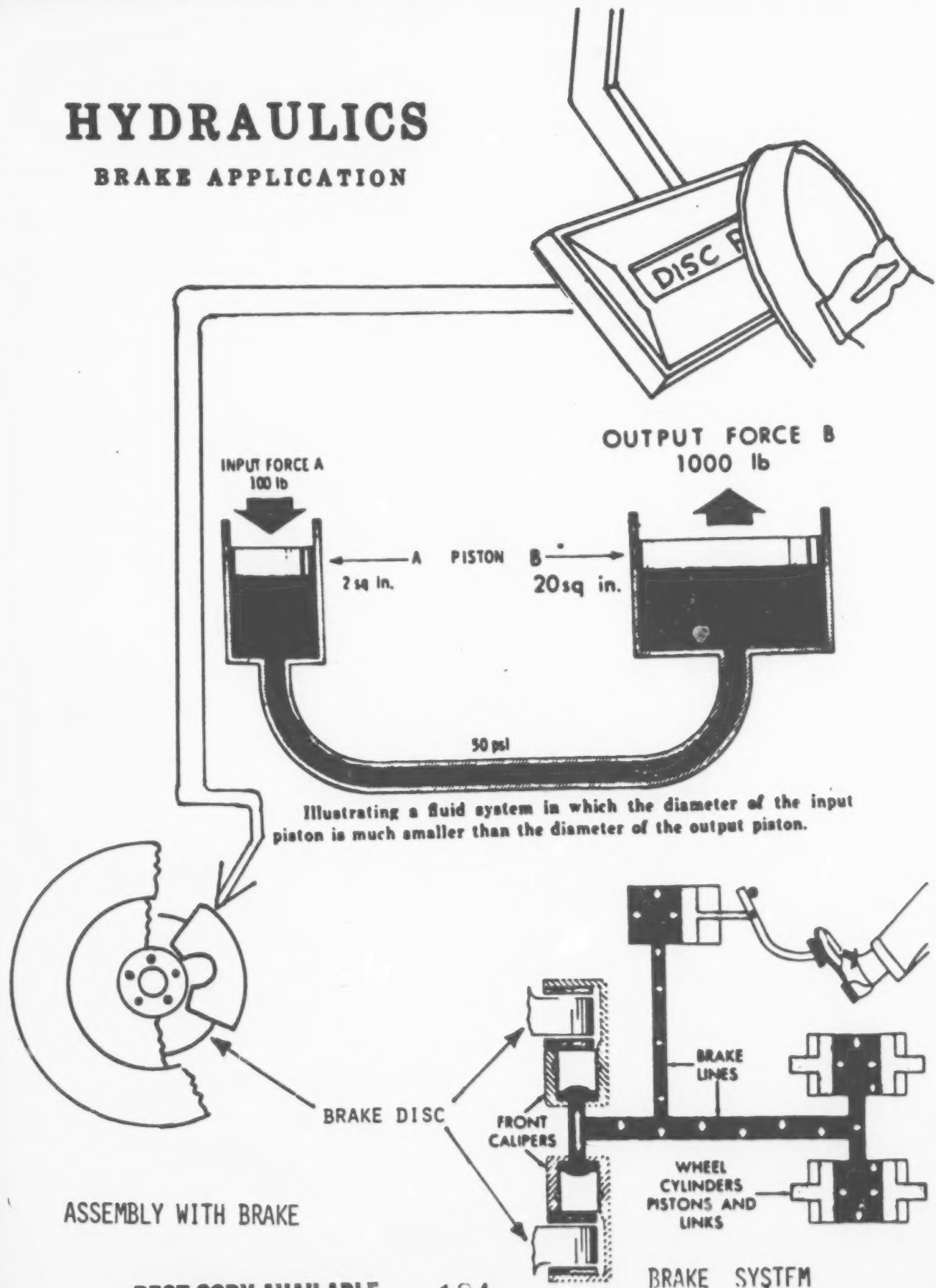
1. Liquids are not compressible.
2. The force exerted by a fluid on its container walls is the same in all directions.
3. Any external pressure exerted on a fluid is transmitted uniformly throughout the fluid and acts perpendicular to the container walls.
4. Work is conserved. Applied force times distance equals output force times distance.
5. The ratio of input and output piston areas determines ideal mechanical advantage.
6. As a piston's area is proportional to the square of its diameter, increasing the output piston's radius greatly increases the mechanical advantage of the system.

MATHEMATICAL CONCEPTS:

1. Force = Pressure x Area
In English units, force is the load in pounds applied to the piston.
Pressure is the pounds per square inch that the piston applies to the liquid. Area is the size of the piston in square inches.
2. Force input x Distance traveled by input piston = Force output x Distance traveled by output piston.
3. (Ideal Mechanical Advantage) $IMA = \frac{\text{Area of output piston}}{\text{Area of input piston}}$ or
 $IMA = \frac{\text{Radius squared of output piston}}{\text{Radius squared of input piston}}$
4. Distance input piston will move = $\frac{\text{Volume of fluid displaced}}{\text{Area of output piston}}$
5. Area of circle-- $A = \pi r^2$
6. Volume of cylinder-- $V = \pi r^2 h$

HYDRAULICS

BRAKE APPLICATION



TITLE: IMPULSE STEAM TURBINE

CATEGORY: INNOVATION

DESCRIPTION:

AFTER THE DEVELOPMENT AND USE OF THE STEAM ENGINE, IT WAS REALIZED THAT A GREAT DEAL MORE ENERGY FROM THE STEAM COULD BE CHANGED INTO MECHANICAL ENERGY WHEN A JET OF STEAM WAS DIRECTED AT A WHEEL WITH BLADES ON ITS EDGE. THIS BLADE WAS KNOWN AS A TURBINE. ONCE THE HIGH ENERGY STEAM MOLECULES HIT THE BLADES OF THE TURBINE, THE TURBINE WAS THEN SET INTO A ROTATIONAL MOTION. THIS ROTATIONAL MOTION WAS CONVEYED THROUGH A MOVING SHAFT TO THE ROTOR OF AN ELECTRIC GENERATOR. THE COIL OF THE ROTOR MOVING IN A MAGNETIC FIELD THEN PRODUCED ELECTRIC ENERGY.

TITLE: IMPULSE STEAM TURBINE

CATEGORY: INNOVATION

SCIENCE CONCEPTS:

1. FOSSIL FUELS ARE NONRENEWABLE. SINCE THESE FUELS CANNOT BE REPLACED, THE COST OF DERIVING ENERGY FROM THIS SOURCE IS EXPENSIVE,
2. COMBUSTION OCCURS WHEN A MATERIAL REACHES ITS POINT OF DECOMPOSITION,
3. ENERGY IS TRANSFERRED FROM CHEMICAL ENERGY TO HEAT ENERGY,
4. THE BOILING POINT OF WATER IS 100°C OR 212°F ,
5. AS WATER REACHES ITS BOILING POINT THE PROCESS OF EVAPORATION BEGINS. AT THIS POINT THE WATER MOLECULES CHANGE FROM A LIQUID TO A GAS,
6. THE KINETIC MOLECULAR THEORY STATES THAT ALL MATTER IS MADE OF MOLECULES. AS THE TEMPERATURE OF THE MOLECULES INCREASES SO DOES THE MOVEMENT OF THE MOLECULES. AS THE MOVEMENT OF THE MOLECULES INCREASES SO DOES THE PRESSURE INSIDE THE CLOSED CONTAINER,
7. AS A GIVEN AMOUNT OF WATER BOILS AND CHANGES INTO STEAM, THE VOLUME OF THE STEAM IS 1700 TIMES GREATER THAN THE VOLUME OF THE WATER,
8. IF STEAM CONDENSES IN A CLOSED CONTAINER, A PARTIAL VACUUM IS CREATED,
9. ENERGY CONVERSION OCCURS AS ENERGY IS BEING TRANSFERRED FROM HEAT TO MECHANICAL ENERGY.
10. AS ENERGY IS BEING CONVERTED FROM ONE FORM TO ANOTHER THE LAW OF CONSERVATION OF ENERGY IS PRESENT. THIS LAW STATES THAT ENERGY CAN NEITHER BE CREATED OR DESTROYED. IN A CLOSED SYSTEM THE TOTAL AMOUNT OF ENERGY IS ALWAYS CONSERVED. THIS LAW IS ALSO KNOWN AS THE FIRST LAW OF THERMODYNAMICS.
11. ENERGY IS NEEDED FOR WORK TO BE DONE.

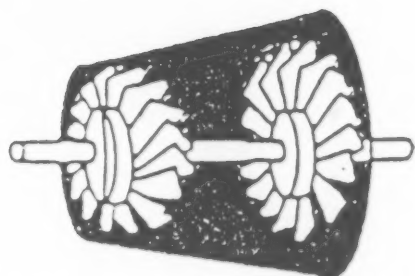
SCIENCE CONCEPTS:

12. WORK IS THE RESULT OF A FORCE ACTING ON A BODY AND MOVING IT THROUGH A DISTANCE. A FORCE IS DEFINED AS A PUSH OR A PULL.
13. THE ESSENTIAL PARTS OF A LARGE ELECTRIC GENERATOR ARE LARGE ELECTROMAGNETS, COILS OF WIRE, AND A SOURCE OF ENERGY TO TURN THE COILS OF WIRE IN THE MAGNETIC FIELD.
14. A MAGNETIC FIELD IS SAID TO EXIST IN A REGION WHERE MAGNETIC FORCES CAN ACT.
15. ELECTROMAGNETIC INDUCTION IS THE PRODUCTION OF AN ELECTRIC CURRENT BY A CHANGING MAGNETIC FIELD.

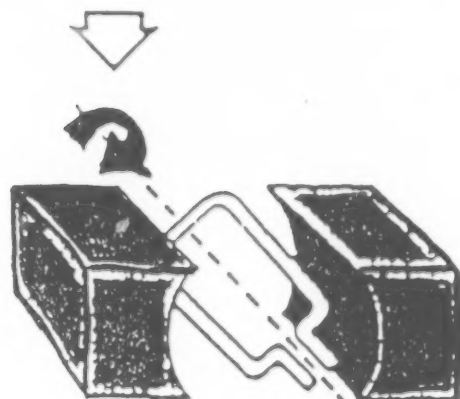
MATH CONCEPTS:

1. UNIT OF WORK $W = F \times D$
2. HEAT/ WORK $W = J \times H$
 $W = \text{WORK DONE (FT. LBS.)}$
 $H = \text{HEAT (B.T.U.)}$
 $J = \text{JOULE'S EQUIVALENT (777.8)}$
3. MULTIPLICATION OF DECIMALS
4. POWER (Hp.) = $\frac{\text{FORCE} \times \text{VELOCITY}}{33,000}$
5. ORDER OF OPERATIONS

IMPULSE STEAM TURBINE



Steam turning turbine blades



Coil turning between poles of electromagnet

CONSERVATION OF ENERGY:
IN A CLOSED SYSTEM-ENERGY IS ALWAYS CONSERVED

$$\text{WORK (ft. lbs.)} = \text{FORCE} \times \text{DISTANCE}$$

ELECTROMAGNETIC INDUCTION:

$$V = N \times \frac{\text{CHANGE IN FLUX}}{\text{CHANGE IN TIME}}$$



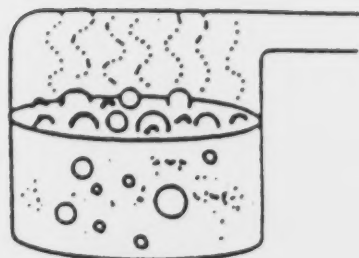
Electric current produced



IMPULSE STEAM TURBINE



Burning of
fossil fuel



Water boiling



COMBUSTION OCCURS WHEN A MATERIAL REACHES
ITS POINT OF DECOMPOSITION

ENERGY CONVERSION:

CHEMICAL ENERGY $\longrightarrow$ HEAT ENERGY

KINETIC MOLECULAR THEORY:

INCREASED MOVEMENT OF MOLECULES
AS TEMPERATURE INCREASES

EVAPORATION: $\text{H}_2\text{O} \xrightarrow{\Delta} \text{H}_2\text{O} \uparrow$

TITLE: IMPULSE WATER TURBINE.

CATEGORY: INNOVATION

DESCRIPTION:

WATER ENTERED THE TURBINE AND HIT THE BLADES THROUGH A CYLINDER. THE WATER WAS DEFLECTED BY GUIDE VANES IN THE CYLINDER TO STRIKE THE BLADES(TURBINE VANES). THE FORCE OF THE WATER, AS WELL AS A REACTION EFFECT SPUN THE TURBINE. THE SPINNING ACTION AND THE RESULTING POWER WERE THE PRODUCT OF IMPULSES AND REACTIONS THAT TAKE PLACE AS SWIFT-MOVING WATER FLOWS WITHIN A RESTRICTED AREA THROUGH SPACES FORMED BY THE BLADES. AN ELECTRIC GENERATOR CAN BE SET UP BY USING THE ROTATING SHAFT OF THE WATER WHEEL AS THE ARMATURE OF THE GENERATOR AND APPLYING AN ELECTRIC FIELD FROM AN EXTERNAL SOURCE. THE MECHANICAL ENERGY OF THE ROTATING SHAFT IS CONVERTED INTO ELECTRICAL ENERGY AS THE ARMATURE ROTATES IN THE FIELD.

TITLE: IMPULSE WATER TURBINE

CATEGORY: INNOVATION

SCIENCE CONCEPTS:

1. Waterpower is a renewable source of energy.
2. Water Cycle:
 - A. Evaporation of water from the earth's surface collects in the atmosphere as vapor.
 - B. Condensation occurs in these clouds of vapor. Water falls back to the surface of the earth.
3. Work is the result of a force acting on a body and moving it through a distance.
4. Energy is needed for work to be done.
5. Energy conversion occurs as energy is being transferred from kinetic to mechanical energy.
6. Simple Machine - A device that helps you do work by increasing force, increasing speed, or changing the direction of the force.

Wheel and Axle - A simple machine that is a type of lever.

Lever and Fulcrum - A bar or board that is free to pivot about a fixed point called the fulcrum.

Gears - A kind of wheel-like machine that acts like a lever.
7. Friction - A force that acts to slow down a moving object that is passing through or against a material. A force is a push or a pull.
8. As energy is being converted from one form to another the law of conversion of energy is present. This law states that energy can neither be created nor destroyed. In a closed system the total amount of energy is always conserved. This law is also known as the first law of thermodynamics.

TITLE: IMPULSE WATER TURBINE

CATEGORY: INNOVATION

SCIENCE CONCEPTS:

9. Mechanical Advantage - A comparison of the force needed to do work directly with the force applied to a machine.
10. The essential parts of a large electric generator are large electromagnets, coils of wire, and source of energy to turn the coils of wire in the magnetic field.
11. A magnetic field is said to exist in a region where magnetic forces can act.
12. Electromagnetic induction is the production of an electric current by a changing magnetic field.

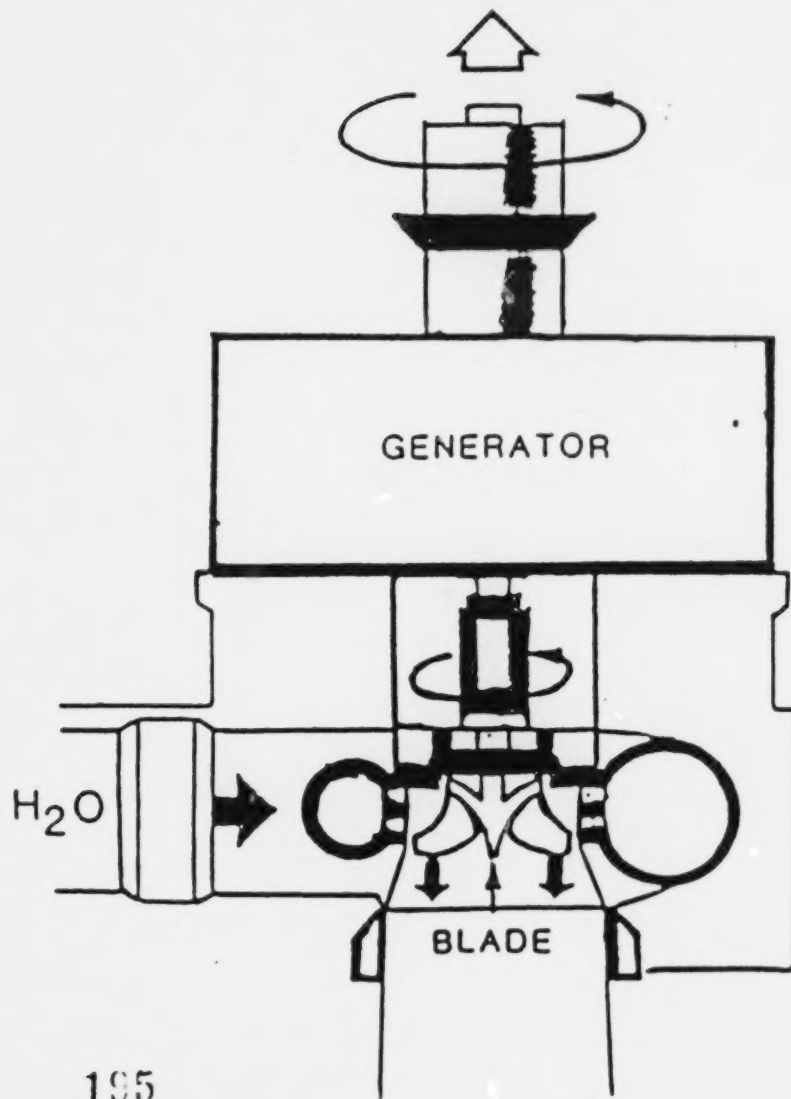
MATH CONCEPTS:

1. Work (Ft. Lbs.) = Force x Distance
2. Multiplication of rational numbers
3. $P = Q \times H$

Potential Water Power = (Q) volume of water flowing past site per unit of time x fall of water (Distance from site to top of wheel)
(H)

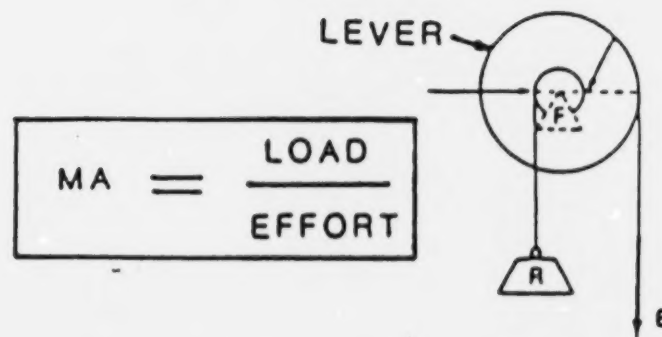
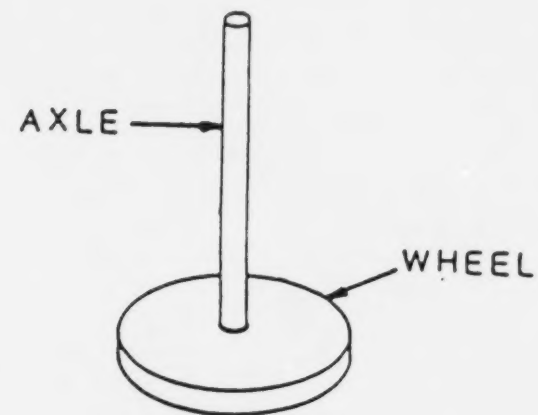
4. Ratios
5. Efficiency (%) = $\frac{\text{Output}}{\text{Input}} \times (100)$
6. Power = $\frac{\text{Force (lb.)} \times \text{Velocity}}{33,000}$

IMPULSE WATER TURBINE



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$$\text{WORK (ft. lbs.)} = \text{FORCE} \times \text{DISTANCE}$$



$$MA = \frac{\text{LOAD}}{\text{EFFORT}}$$

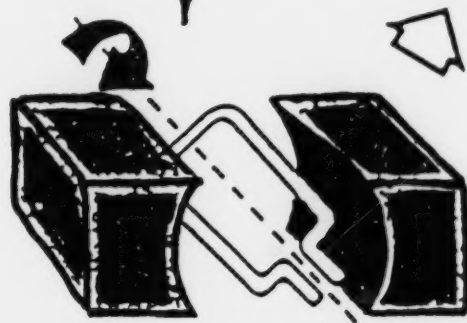
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IMPULSE WATER TURBINE

ELECTROMAGNETIC INDUCTION:

$$V = N \times \frac{\text{CHANGE IN FLUX}}{\text{CHANGE IN TIME}}$$



$$\text{WORK (ft. lbs.)} = \text{FORCE} \times \text{DISTANCE}$$

TITLE: Incandescent Lights

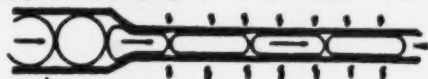
DESCRIPTION:

This transparency shows the concepts involved in the incandescent lamp. The basic principle shows the passing of electrons through a resistance. In doing this, heat and light are given off. To further the usefulness of the lamp, a high melting point metal is used as filament and the atmosphere inside the bulb consists of an inert gas mixture.

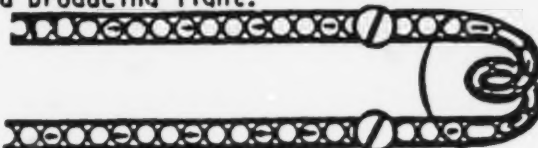
SCIENCE CONCEPTS

Incandescent Lamp

1. An electric circuit is a pathway through which electric current travels or through which electrons flow freely.
2. When electron movement is slowed down, heat and light are generated!



3. In the incandescent lamp, electrons of the tungsten atom have a difficult time making their way through the small diameter of the high - resistance wire when it is tightly coiled. The coiling constricts electric current causing much friction resulting in the wire becoming white -hot and producing light.



4. Resistance increases as:
 - a. diameter of wire gets smaller
 - b. length of wire increases
 - c. temperature of wire increases
5. Intensity of a light source is measured in candle power or lumens. The lumen is the total amount of light actually given off by a source.

1 candle power = 12.57 lumens.

6. Inert gas mixture of Nitrogen and Argon is used inside glass bulb rather than Oxygen to prevent oxidation and rapid burning of tungsten filament.

TITLE: Incandescent Lights

DESCRIPTION:

This transparency shows the concepts involved in the incandescent lamp. The basic principle shows the passing of electrons through a resistance. In doing this, heat and light are given off. To further the usefulness of the lamp, a high melting point metal is used as filament and the atmosphere inside the bulb consists of an inert gas mixture.

MATH CONCEPTS:

Incandescent Lamp

1. Ohm's law: $I = \frac{V}{R}$

Ampere of current (I) = Voltage (V) divided by resistance (R).

2. Jowle's law: The heat developed in a conductor is directly proportional to the resistance of the conductor, the square of the current, and the time the current is maintained.

$$H \text{ (heat in joules)} = I^2 \times R \times T$$

3. Energy in electric circuit measured in watt - hours.

$$\text{Watt - hours (w-hr)} = \text{Watts} \times \text{hours}$$

$$1000 \text{ W-hr} = 100 \text{ W} \times 10 \text{ hrs.}$$

$$\text{one KWH (kilowatt hour)} = 1000 \text{ watt hrs.}$$

4. A joule is a unit of electrical energy.

$$1 \text{ joule} = \frac{1 \text{ amp. (current)} \times 1 \text{ ohm (resistance)}}{1 \text{ sec}}$$

or

$$1 \text{ Joule} = \frac{1 \text{ Volt}}{1 \text{ Sec}}; \quad 1 \text{ joule} = 2.8 \times 10^{-7} \text{ KWH}$$

5. The amount of light we receive from a light source depends upon our distance from that source measured in foot candles.

CP = candle power (amount of light)

d^2 = distance (foot candle)

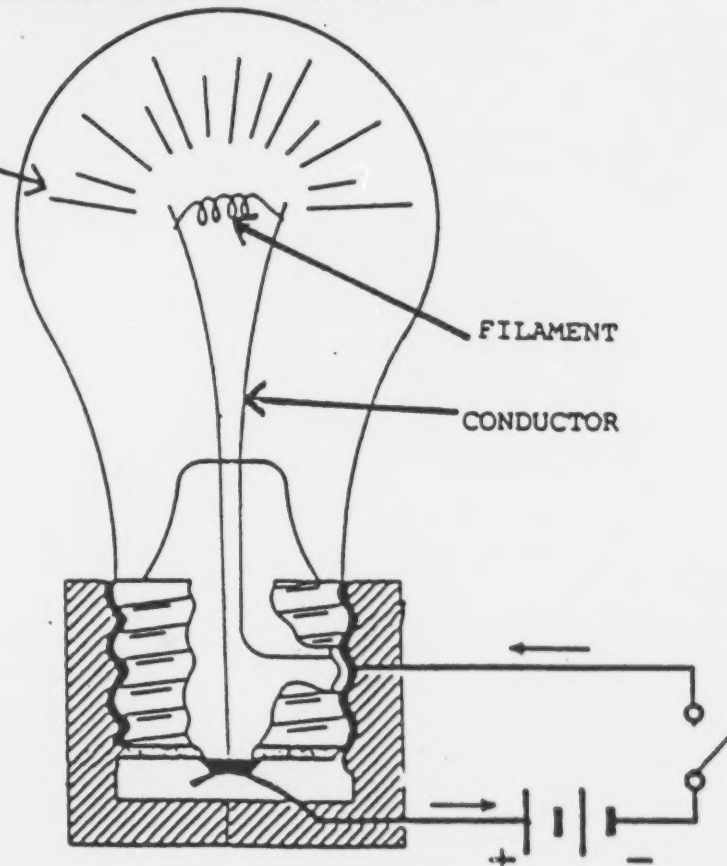
$$\text{illumination} = \frac{CP}{d^2}$$

INCANDESCENT LIGHTS

INERT GAS MIXTURE OF
NITROGEN AND ARGON IN
GLASS BULB PREVENTS
OXIDATION OF FILAMENT.

WATT
$W = I \times V$
HEAT
$H = I \times R \times t^2$

ILLUMINATION = $\frac{CP}{d^2}$



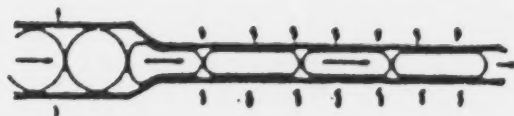
H = HEAT MEASURED IN JOULES
I = CURRENT MEASURED IN AMPERES
R = RESISTANCE MEASURED IN OHMS
t = TIME IN SECONDS

W = WATTS
V = VOLTS
CP = CANDLE POWER IN LUMENS
d = DISTANCE

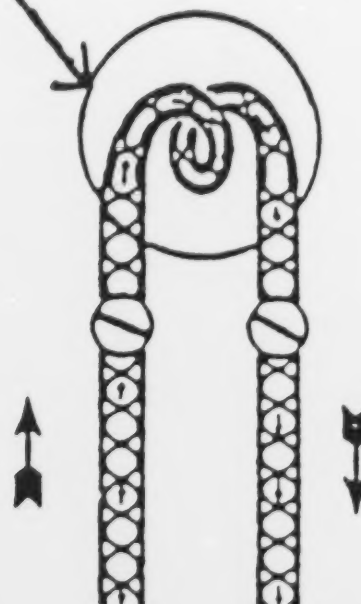
INCANDESCENT LIGHTS

THE ELECTRONS OF THE TUNGSTEN ATOMS
HAVE A DIFFICULT TIME MAKING THEIR
WAY THROUGH THE SMALL DIAMETER OF
THE HIGH RESISTANCE FILAMENT WHICH
CONSTRICTS ELECTRON FLOW CAUSING MUCH
FRICTION RESULTING IN THE WIRE
BECOMING WHITE-HOT AND GIVING
OFF LIGHT.

ELECTRON FLOW THROUGH RESISTANCE.



ELECTRON FLOW THROUGH CONDUCTOR



TITLE: LASER

CATEGORY: INNOVATION

DESCRIPTION:

L A S E R stands for Light Amplification by Stimulated Emission of Radiation. The function of the laser is to absorb a flash of low energy lasting for several thousandths of a second and to release high energy light that lasts only a few millionths of a second. Lasers are used in business and industry in a variety of processes.

SCIENCE CONCEPTS:

1. Light is a form of energy and is made of tiny particles called photons.
2. Energy is the ability to do work.
3. Light travels in straight lines, except when it is refracted.
4. Light may be absorbed, reflected, or radiated.
5. Light may be separated into colors of the visible spectrum: red, orange, yellow, green, blue, indigo, and violet.
6. The visible spectrum is a part of a larger spectrum called the electromagnetic spectrum.
7. The electromagnetic spectrum is made up of radio waves, infrared, visible light, ultraviolet, x-rays, gamma rays, and cosmic rays.
8. The different parts of the electromagnetic spectrum have different wavelengths.
9. Wavelength is the distance from one point of a light wave to the corresponding point on the next wave.
10. A laser utilizes visible/invisible light.
11. The word lases is derived from Light Amplification by Stimulated Emission of Radiation.
12. A laser may be a gas-filled vacuum tube with an anode and a cathode.
13. A vacuum tube is a device containing a vacuum/gas in which electrical impulses can be transmitted through a conductor at the speed of 186,000 miles per second.
14. The speed of light is 186,000 miles/sec.
15. The gas in the vacuum tube ionizes (becomes electrically charged) and causes a current to flow.

TITLE: LASER

CATEGORY: INNOVATION

MATHEMATICAL CONCEPTS:

1. Exponents offer a convenient way of expressing repeated factors.
2. An exponent is a number written to the upper right of a non-zero whole number called a superscript. It represents how many times the whole number is multiplied by itself.

Example: $(\text{base})^{\text{exponent}} = \text{power}$

$$\begin{aligned}(3)^2 &= 9 \\ 3 \times 3 &= 9\end{aligned}$$

3. Any product in which one or more factors is repeated may be expressed by means of exponents.

Example: $1.86 \times 10^5 = 186,000 \text{ miles/sec.}$

4. A cycle is a series of events that occur in a sine wave in 360° . These are the events that are generated by one complete revolution of a rotating vector.
5. The frequency of a sine wave is the number of cycles that occur in a specific period of time.
6. The time of one complete cycle is called the period, T. If the frequency represents the number of cycles that occur in 1 second(s), then the period would be found as

$$T = \frac{1}{f} \quad S$$

7. The higher the frequency, the smaller the time in seconds. The units that are commonly used for these shorter times are:

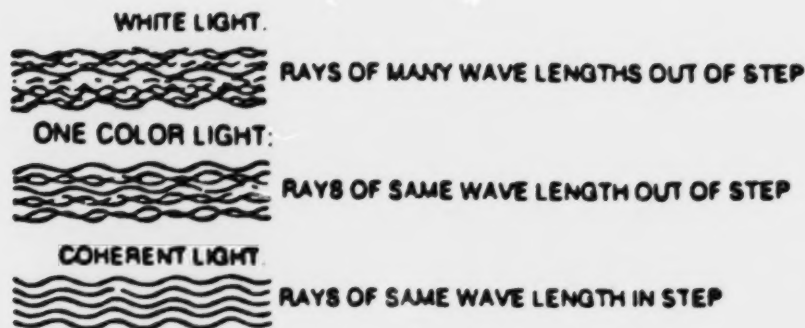
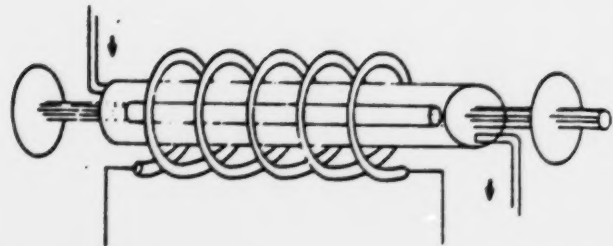
milliseconds, ms = 10^{-3} s
microseconds, μ s = 10^{-6} s
nanoseconds, ns = 10^{-9} s

8. The unit of measurement that is often used is the wavelength. The wavelength, λ (Greek letter Lambda), relates the velocity of transmission and the frequency of the wave.
9. The wavelength is the distance traveled during one cycle. It is calculated with the following formula:

$$\lambda = \frac{\text{velocity}}{\text{frequency}}$$

LASER

THE FUNCTION OF A LASER
IS TO ABSORB A FLASH OF LOW
ENERGY WHITE LIGHT LASTING FOR
SEVERAL THOUSANDTHS OF A SECOND
AND TO RELEASE HIGH ENERGY COHERENT
LIGHT THAT LASTS ONLY A FEW MILLIONTHS OF A SECOND.



LASER APPLICATIONS

COMMUNICATIONS
RANGEFINDERS
AIDS FOR THE BLIND
WELDING
ALARM SYSTEMS
ILLUMINATION
HOLOGRAPHY
DRILLING

EXPONENTS ARE USED TO WRITE
VERY LARGE OR VERY SMALL
NUMBERS.

$$1 \text{ MILLIONTH} = .000001 = 10^{-6}$$

Title: Lift Pump

Category: Innovation

Description:

A pump is a machine for moving liquids and gases. Pumps have many uses in the home and in industry. They are used in mining, irrigation, boilers, atomic engines, air conditioners, wells, home heating systems and city water plants. The pump is one example of a machine that has contributed to the growth of our civilization.

Science Concepts:

Definitions

1. Air pressure - the weight of a column of air.
2. Force - A push or a pull.
3. Vacuum - A condition with a lack of air pressure.
4. Friction - A transfer of energy by rubbing one material on another.

Principles

1. Priming the pump involves adding water to the top of the pump to help seal the piston.
2. Lifting the piston creates a partial vacuum inside the pump. Air pressure pushes water from the water supply into the pump to fill the vacated space. When the piston is pushed down there is an attempt to compress the water which forces a valve in the bottom of the pump to close and forces a valve in the piston to open. On the next lift of the piston, water overflows from the pump and a partial vacuum is again created. The process begins again.
3. The maximum depth the pump will work is determined by the weight of the air. Air pressure is sufficient to support a column of water 34 feet high. Therefore, a lift pump should be able to lift water about 34 feet.

Title: Lift Pump

Category: Innovation

Science Concepts:

4. The lift height is effected by the percent of vacuum achieved.
For example, if a 50% vacuum is achieved the lift height is reduced by 50%. This reduces the lift height from 34 feet to 17 feet.
5. Friction between the water and the pipe is another limiting factor.
It is important to keep this to a minimum, therefore, round pipe is used. Round pipe has much lower surface area for contact between water and pipe and consequently less friction.

Title: Lift Pump

Category: Innovation

Math Concepts:

$$\begin{aligned} \text{I. Maximum depth} &= \frac{\text{Atmospheric pressure (14.7 lbs./sq.in)}}{\text{Weight of Water (.036 lbs./cu. in.)}} \\ &= \frac{14.7}{.036} \times 12 \text{ inches} = 408.3 \text{ inches} \div 12 = 34 \text{ feet} \end{aligned}$$

Beyond this depth the air pressure would equal the weight of the water and the pump would be ineffective. Even at 34 feet all other conditions would have to be perfect. Therefore, recommended depth is 27 feet.

II. Why are pipes cylindrical?

Compare the surface areas of a cylinder and a rectangular prism of equal volume.

Cylinder with base radius of 10 and height of 100 cm.

$$\begin{aligned} V &= \pi r^2 \times h \\ V &= 3.14 \times 10^2 \times 100 \\ V &= 31400 \text{ cm}^3 \end{aligned}$$

Rectangular prism with length of 3.14 cm, width of 100 cm and height of 100 cm.

$$\begin{aligned} V &= l \times w \times h \\ V &= 3.14 \times 100 \times 100 \\ V &= 31400 \text{ cm}^3 \end{aligned}$$

Surface Areas

Cylinder -

$$\begin{aligned} SA &= 2\pi r^2 + \pi d \times h \\ SA &= [2(3.14 \times 10^2)] + (3.14 \times 20 \times 100) \\ SA &= 628 \quad + 6280 \\ SA &= 6907 \text{ cm}^2 \end{aligned}$$

Title: Lift Pump

Category: Innovation

Math Concept

Prism -

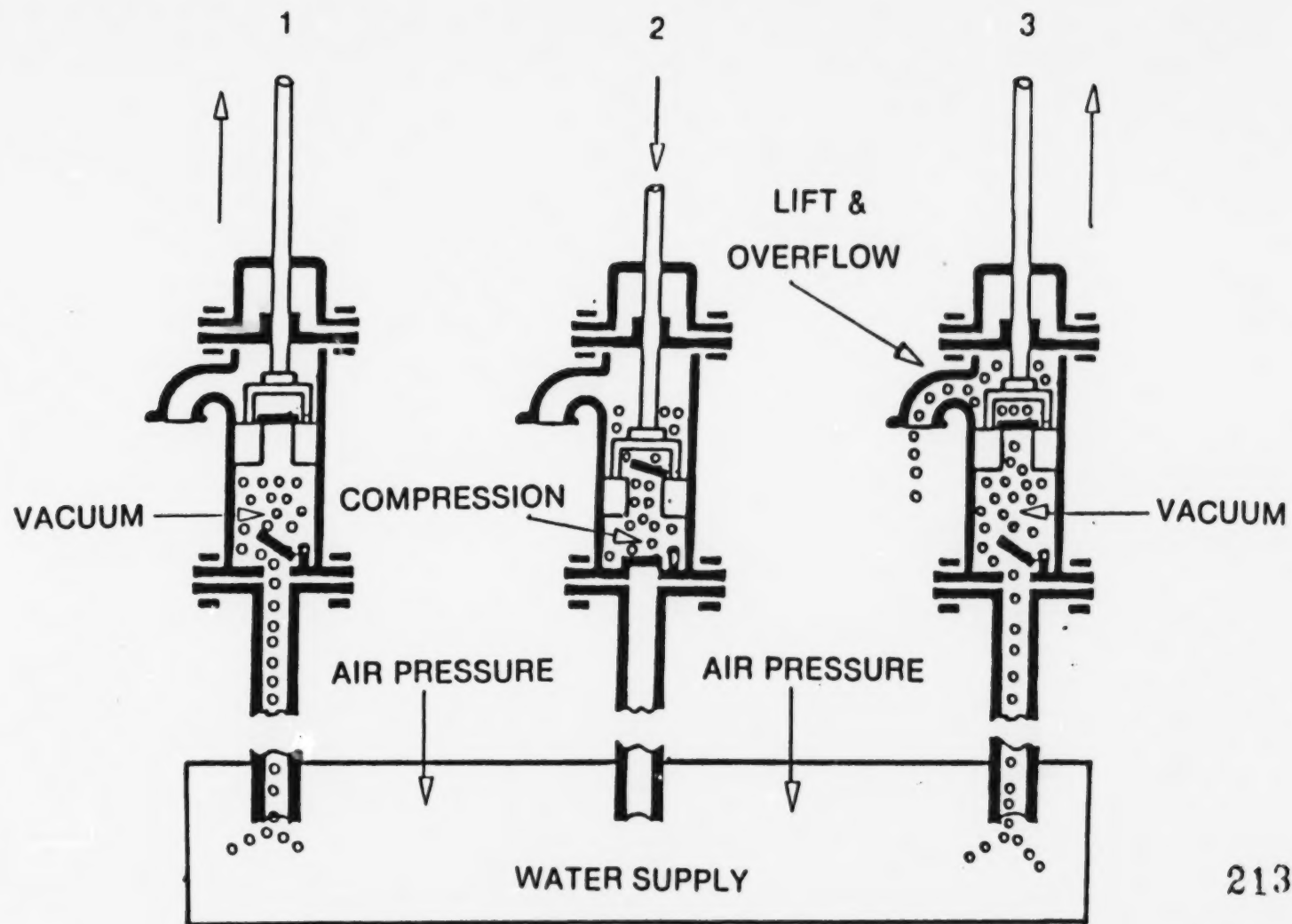
$$\begin{aligned} SA &= 2 (a \times b) + 2 (a \times c) + 2 (b \times c) \\ &= 2 (100 \times 3.14) + 2 (100 \times 100) + 2 (100 \times 3.14) \\ &= 628 \qquad \qquad + 20000 \qquad \qquad + 628 \\ &= 21,256 \text{ cm}^2 \end{aligned}$$

Surface area of cylinder is approximately one third that of a rectangular prism.

Math Skills:

1. Ratio
2. Square and cubic units of measure
3. Exponents
4. Division of decimals
5. Conversion of linear units of measure
6. Area of rectangles
7. Area of circles
8. Volume of rectangular prisms
9. Volume of cylinders
10. Circumference of circles
11. Surface area of rectangular prisms
12. Surface area of cylinders
13. Multiplication of decimals

LIFT PUMP



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Title: Light Emitting Diodes (LED)

Category: System

Description:

LED is a device that gives off light energy when electrical current is passed through its p-n junction.

LED's are useful for low-voltage display devices, such as calculators and digital watches.

Science Concepts

1. The law of conservation of matter and energy.
2. Light possess energy in the form of particles called photons.
3. Certain semiconductor materials emit light when the PN junction is forward-biased.
4. The semiconductors used to emit radiation and to conduct when forward-biased are called light-emitting diodes or LED's.
5. Reverse biasing a LED produces an effect similar to reverse biasing in an ordinary diode, that is, no current flow or no light emitted in LED's.
6. Light emitting semi-conductor materials include gallium arsenide and gallium phosphide.
7. By combining various materials and by varying doping levels, the gallium arsenide and gallium phosphide diodes can be made to emit different wavelengths or colors of light.
8. LED's usually emit red, yellow and green color through electromagnetic radiation.
9. Electromagnetic radiation can be distinguished by its wavelengths.
10. Visible light is near the center of the electromagnetic spectrum.
11. Within the range of visible light, we preceive colors depending on the wavelength of the light beginning with violet, the shortest to the longest; which is red.
12. The human eye bärely detects the radiation of gallium, arsenic, phosphorus and nitrogen.

13. Due to the limitation of the human eyesight for the radiation spectrum manufacturers have discovered a way to convert the wavelength of radiation from infrared radiation to visible green light by the use of a phosphorescent screen.
14. The color emitted by LED's depends on its composition. GaAsP as an example of the most common compound used.
15. GaAsP (gallium arsenide phosphide) LED's output is in the wavelength region of 670 nanometers or perceived by the human eye as the color red.
16. Blue LED's are experimental, especially in solidstate color TV picture displays.
17. Light brightness is dependent upon the number of photons released by the recombination of charge carriers inside the LED.
18. The higher the forward bias voltage, the greater the brightness of light emitted.
19. The light output is proportional with the amount of forward current.
20. In application, LED's which are low-heat-generating devices are used as a pilot for the smoke alarm, used in visual alphanumerics (letter and numbers) readout displays involving digital circuitry to drive various segments, in replacing of standard light sources (incandescent bulbs, fluorescent displays and neon bulbs) due to longer expected life, low voltage operation compatible with integrated circuits, fast response times and low cost.
21. Under development is the use of LED's in solidstate color TV picture display made of arrays of LED's, emitting green, red and blue light.
22. LED's are used in fiber optics communication systems in airplanes.

Title: Light Emitting Diodes (LED)

Category: System

Mathematical Concepts:

1. Light output is proportional to amount of forward current - ratios and proportions.
2. Ohm's Law - Transform a formula to express a particular variable in terms of other variables $E = I \times R$.
3. Reading and interpreting graphs, charts and data - (specification sheet)

PART	IF(MAX)	IR(MAX)	DEM.	VCA	TYPE
LED 1	200ma	.1ma	0.25	1.8	GaASP

4. Change a decimal number into binary form and change binary number to decimal form.
5. The red lamp can be made brighter by selecting an appropriate load resistor. The formula for the load resistor is

$$R_L = \frac{V_{cc} - V_f}{I_f}$$

Where V_{cc} = Supply voltage

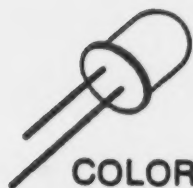
V_f = Forward bias from
manufacturer's data sheet

I_f = forward current from manufacturer's data sheet

6. The resistor power rating required in the LED circuit is also readily calculated because we know the resistance and current. The power is

$$P = I_F^2 R$$

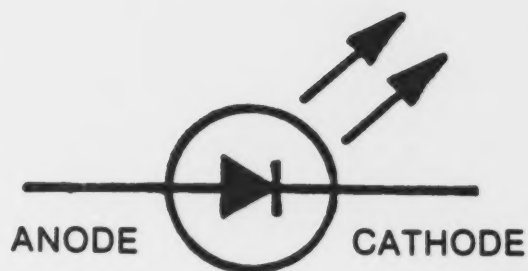
LIGHT-EMITTING DIODES



COLORED LED'S



INFRARED



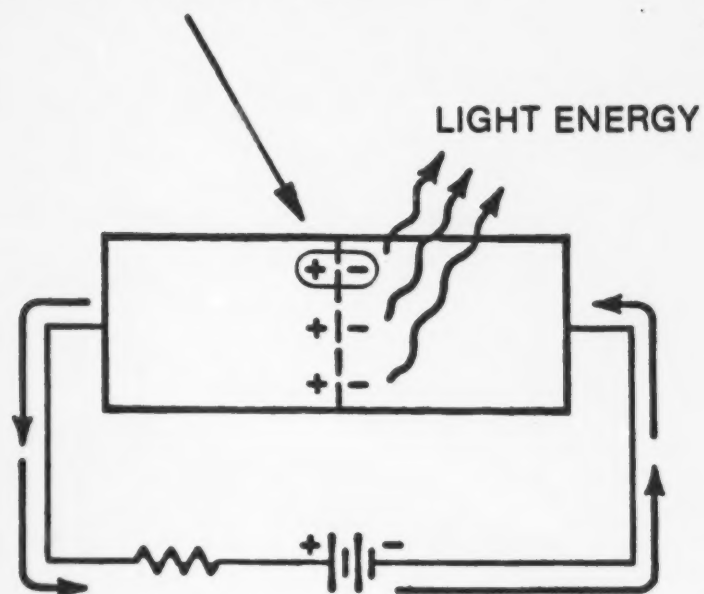
BAR GRAPH



7-SEGMENT

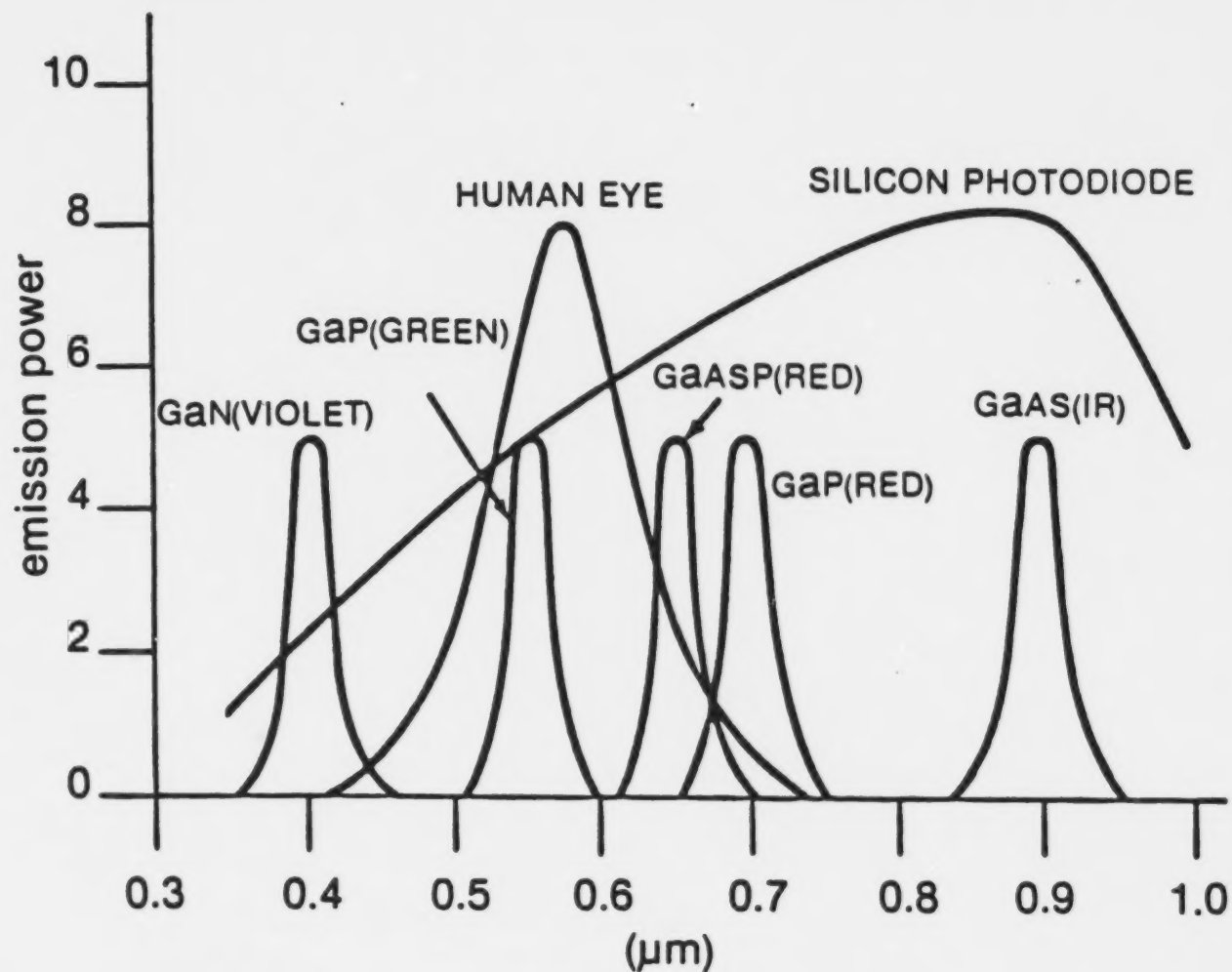
LIGHT-EMITTING DIODES

ELECTRONS AND HOLES COMBINE



ELECTRONS MOVE FROM A HIGH ENERGY LEVEL TO A LOW ENERGY LEVEL. EXCESS ENERGY IS GIVEN OFF IN THE FORM OF HEAT AND LIGHT.

LIGHT-EMITTING DIODES

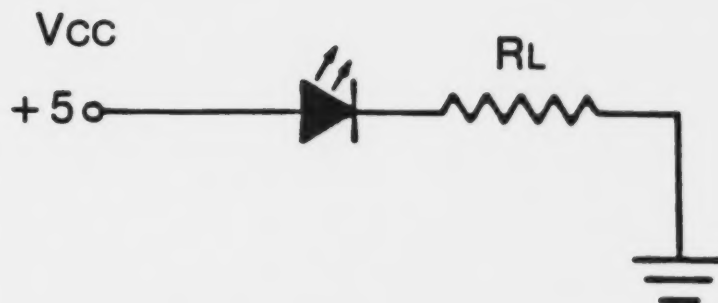


VISIBLE LIGHT IS FROM .4 TO .8 MICROMETERS. WITHIN THE RANGE OF VISIBLE LIGHT, WE SEE COLORS DEPENDING ON THE WAVELENGTH OF THE LIGHT.

LIGHT-EMITTING DIODES

PART	IF(MAX)	IR(MAX)	DEM.	VF	TYPE
LED 1	200ma	.1ma	0.25IN.	1.8	GaASP

SPECIFICATION CHART



$$R_L = \frac{V_{CC} - V_F}{I_F}$$

Title: Logic Inverter

Category: System

Description:

A logic is a device that inverts the level of the input signal.

It will produce a low output when the input is high and a high output when the input is low.

Science Concepts:

1. The Atomic Theory of Matter
2. Free Electrons
3. Ions and the generation of electrons
4. Current flow in circuits
5. Elements that have one to three electrons in the outermost shell are the best electrical conductors or carriers of an electrical current.
6. The process of generating electricity - should enough free electrons break away from the outermost shell of atoms and move from the negative to the positive pole of the circuit, electrical current will flow.
7. The electrical circuit is composed of three fundamental components. The source or energy, the load, which converts the energy supplies into other forms of energy (heat, light and motion), and the switch or conductors that permit the flow of electrons.
8. Kirchhoff's Law of voltage. The sum of all the individual voltage drops around a circuit is equal to the voltage of the source.
9. Ohm's Law - The current in amperes that will flow in any circuit is directly proportional to the pressure applied in volts and inversely proportional to the circuit resistance in ohms. The law shows the relationship that exist between electrical potential, electrical resistance, and the strength of the current flowing.
10. Amplification is an enlargement of an input signal by an amplifier which may provide voltage, current, and power gains in varying combinations.

Title: Logic Inverter

Category: System

Science Concepts:

11. Transistors can be used to provide amplification. They provide the power gain that is needed.
12. The bipolar junction transistor is used in most circuits and are similar to junction diodes, except for one more junction included.
13. The bipolar junction transistor is manufactured in two polarities; NPN and PNP.
14. A P- type semiconductor region is located between two N - Type regions.
15. The polarity of these regions is controlled by the valence of the materials used in the doping process.
16. The transistor regions are named emitter, base, and collector.
17. The emitter is very rich in current carriers or holes, which send carriers into the base region and then to the collector.
18. The collector "collects" the current carriers and is highly doped.
19. The emitter "emits" the current carriers and is heavily doped.
20. The base acts as the control region for the flow of current and is very lightly doped.
21. The bipolar transistor has both holes and electrons taking part in the current flow.
22. The two transistor junctions must be biased properly. You cannot replace an NPN transistor with a PNP transistor. The polarities will be wrong.
23. There are three modes of bipolar transistor operation. Cut-off, linear, and saturation.
24. In the saturation mode, both the emitter - base and collector-base junction are forward biased resulting in the transistor conducting heavily.

Title: Logic Inverter

Category: System

Science Concepts:

25. A saturated transistor can be compared with a closed switch. The voltage drop across will be zero.
26. A cutoff transistor can be compared with an open switch. The voltage drop across it will be equal to the supply voltage.

Title: Logic Inverter

Category: System

Mathematical Concepts:

- 1) Review and apply the principles of addition, subtraction, multiplication and division of decimals to a formula.
- 2) Read and write numbers in scientific notation.
- 3) Use the laws of exponents to simplify terms.
- 4) Write a binary number in decimal form and a decimal number in binary form.
- 5) Kirchoff's Voltage Law - The sum of voltage drops around a closed loop circuit equals the voltage at the source....the algebraic sum of all voltage around a closed loop circuit will equal zero.
- 6) Formula for determining the current transfer ratio for a circuit.

$$h_{FE} = \frac{I_C}{I_B}$$

I_C - collector current
 I_B - base current

- 7) Formula for Saturation

$$I_C = \frac{V_{CC}}{R_C} \qquad I_B = \frac{I_C}{h_{FE}}$$

where

V_{CC} = Applied Voltage

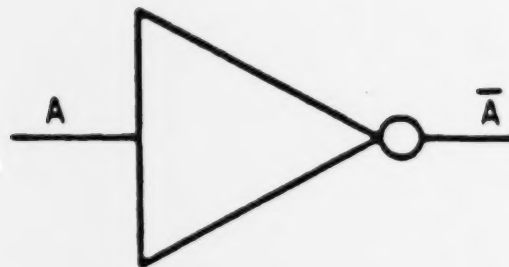
I_C - current on collector

R_C - Resistor on the collector

h_{FE} - voltage gain

- 8) From a truth table, you will be able to identify the logic function being performed.

LOGIC INVERTER



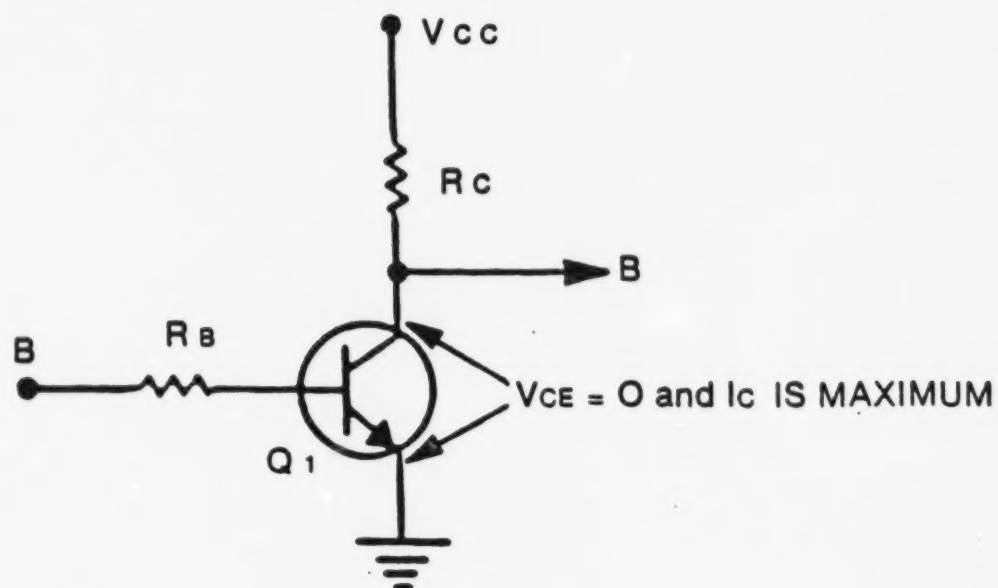
LOGIC INVERTER SYMBOL

INPUT	OUTPUT
A	$\bar{A}$
0	1
1	0

LOGIC INVERTER TRUTH CHART

LOGIC INVERTER

SATURATED TRANSISTOR LOGIC

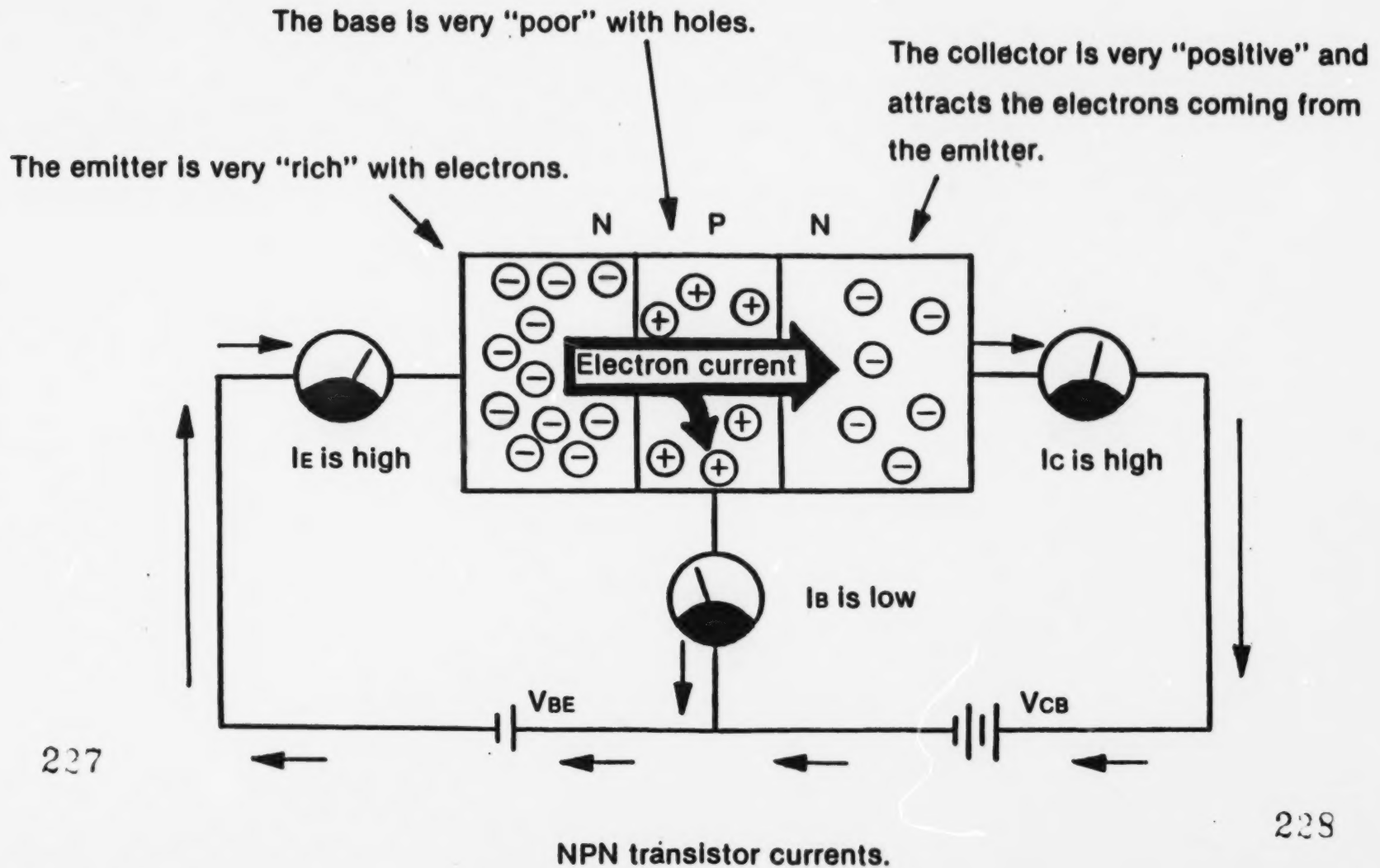


$$I_C = \frac{V_{CC}}{R_C}$$

$$I_B = \frac{I_C}{h_{FE}}$$

Saturation occurs when the transistor is conducting at its maximum current flow and the voltage between the collector and the emitter is equal to zero.

LOGIC INVERTER



TITLE: MAGNETIC COMPASS

CATEGORY: INNOVATION

DESCRIPTION:

A magnetic compass is an instrument which indicates direction. Small ships and boats depend entirely on magnetic compasses for determining their direction. The magnetic compass is one of the oldest of the navigator's instruments. Initially, the compass was used to indicate north but later the concept of marking other directions was introduced.

SCIENCE CONCEPTS:

1. The Earth is a huge magnet with a magnetic field.
2. A magnetic field is a group of imaginary lines along which magnetic force acts. These lines emanate from the North Pole and enter the South Pole, forming closed loops.
3. Like magnetic poles repel one another, while unlike poles are attracted.
4. The Earth has both a geographic North Pole and a magnetic North Pole.
5. The Earth's magnetic poles are over one thousand miles from its geographic poles.
6. A lodestone is a natural magnet.
7. Lodestones are composed of iron compounds that have magnetic properties.
8. The functional unit of a compass is a magnet with its North seeking pole pointing towards the earth's magnetic North Pole.
9. Variation is the difference between the magnetic North Pole and the true geographic North Pole.
10. Variation exists because the magnetic North Pole changes its location.

CATEGORY: INNOVATION

1. Degree measures - Longitude and Latitude.
2. Concept of 60 equal divisions of a degree called minutes and 60 equal divisions of a minute (3600 equal divisions of a degree) called seconds.
3. Concept of variation. Variation is equal to the difference between magnetic and true north.
4. Absolute Value in computing variation. Variation is always stated positively.
---It is called easterly (E) if the compass needle indicates magnetic north is east (or to the right) of true north.

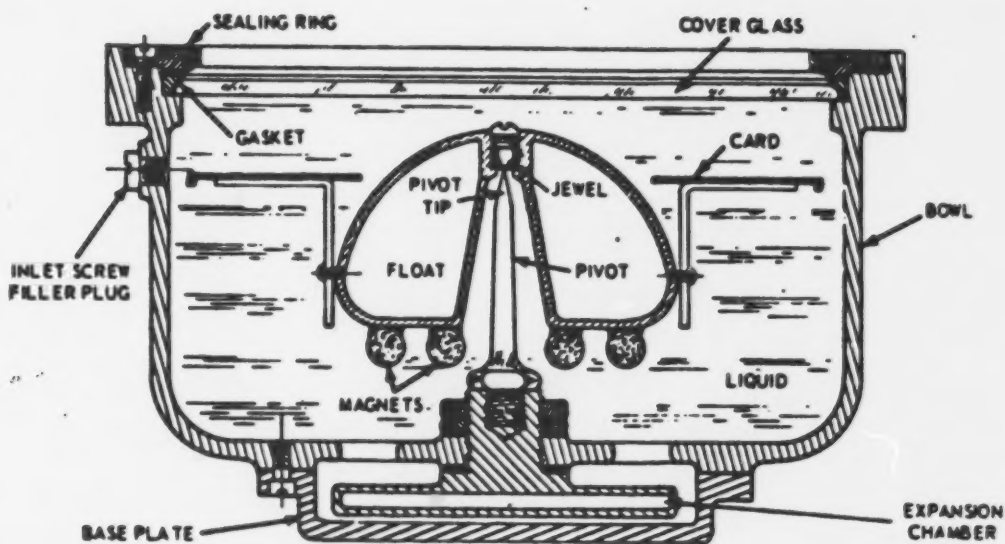
---It is called westerly (W) if the compass needle indicates magnetic north is west (or to the left) of true north.
5. Variation can be different for different locations due, in part, to changes in the geometric alignment of true and magnetic north.
6. Choice between and use of addition or subtraction in correcting from compass reading to true heading or "uncorrecting" from true heading to compass reading.

---When correcting: add easterly variations to the compass reading.
 subtract westerly variations to the compass reading.

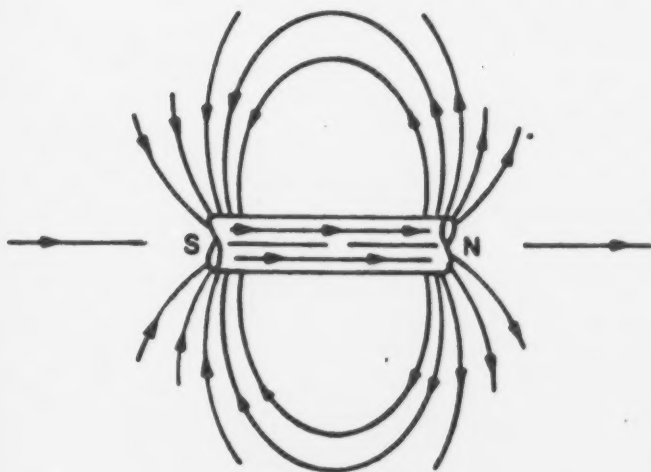
---When uncorrecting: add westerly variations to the true heading.
 subtract easterly variations to the true heading.



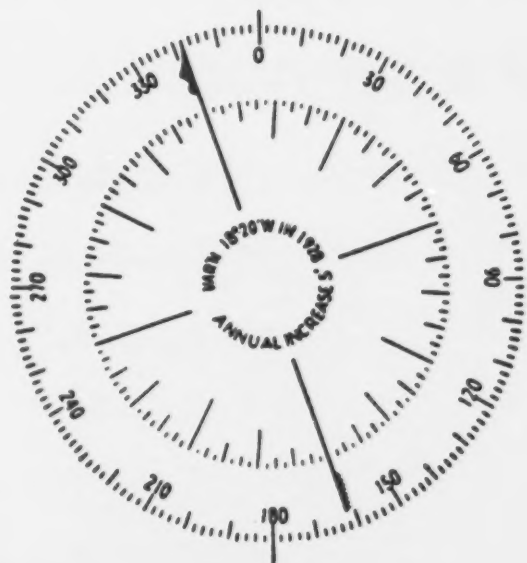
THE MAGNETIC COMPASS



MAGNETIC LINES OF FORCE



TRUE AND MAGNETIC NORTH



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TITLE: MICROWAVE OVEN

CATEGORY: INNOVATION

DESCRIPTION:

The microwave oven heats only foods that contain water. The operation of the oven depends on a special property in water and a high-energy transmitting device called a megatron. A water molecule consists of a negative oxygen atom with two positive hydrogen atoms. Its shape makes it a dipole which means it has a positive and negative end. When placed in an electric field the positive ends turn toward the negative end of the field and vice versa. The field changes 2450 million times per second. This action heats food in the oven.

SCIENCE CONCEPTS:

1. Light is a form of energy.
2. Light is made up of tiny particles called photons.
3. Light travels in straight lines called rays, except when it is refracted.
4. Most objects that emit light rays also emit heat rays.
5. Heat and light rays are part of the electromagnetic spectrum.
6. Heat and light rays are also known as infrared, or radiant-heat rays.
7. Their wavelengths are longer than those of visible light.
8. Wavelength is the distance from one point of a light wave to the corresponding point on the next wave.
9. Infrared rays are effective for heating food.
10. Water molecules have a natural vibrating frequency in the infrared or microwave region.
11. Food contains a large amount of water.
12. When food is exposed to radiation in microwaves, the heating effect is greater and less power is used than in other methods of cooking.
13. Power is the rate at which work is done.
14. The use of less power results in the conservation of energy.
15. Energy is the ability to do work.
16. Energy can neither be created nor destroyed, but its form can be changed.
17. In a microwave oven, two changes take place in the form of energy.
18. Hertz energy from the power lines are converted into megahertz by the magnetron vacuum tube.

SCIENCE CONCEPTS:

(CONTINUED)

19. A magnetron vacuum tube is about 5.5 inches overall and is cooled by aluminum fins that conduct heat energy away from its plate.
20. The microwave energy which leaves the tube travels down a metallic tube called the waveguide.
21. The microwave energy then encounters an electric fan known as the stirrer which uniformly distributes the microwave energy over the entire surface of the food being cooked.
22. The microwave energy generated is conducted to the food which sets the food's molecules violently in motion producing heating and cooking.
23. Microwaves travel freely through glass and porcelain and remains cool throughout the cooking cycle.

TITLE: MICROWAVE OVEN

CATEGORY: INNOVATION

MATHEMATICAL CONCEPTS:

1. Exponents offer a convenient way of expressing repeated factors.
2. An exponent is a number written to the upper right of a non-zero whole number called a superscript. It represents how many times the whole number is multiplied by itself.

Example: (base)^{exponent} = power

$$\begin{aligned}(5)^2 &= 25 \\ 5 \times 5 &= 25\end{aligned}$$

3. Any product in which one or more factors is repeated may be expressed by means of exponents.

Example: $10^6 = 1,000,000$

4. Metric prefixes represent power of ten multiples or submultiples.

Multiplication
Factor

Prefix

Symbol

10^{18}

exa

E

10^{15}

peta

P

10^{12}

tera

T

10^9

giga

G

10^6

mega

M

10^3

kilo

5. The unit of frequency is the Hertz (Hz). Large and small units of any quantity can be formed by attaching prefixes of the metric system.

Example: 1 GHz = 1 giga Hertz

6. Microwaves have wavelengths between 30 cm and 1 mm, that is frequencies between 1 GHz (1,000 MHz) and GHz.
7. The electrical power consumed by a microwave oven is expressed in units called watts.

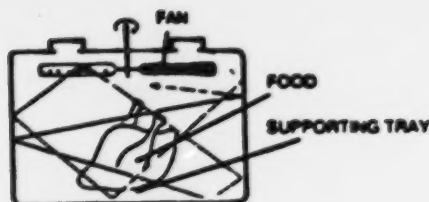
It can be calculated using this formula:

Power = Voltage x current

Example: P = 120 Volts x 4 amperes

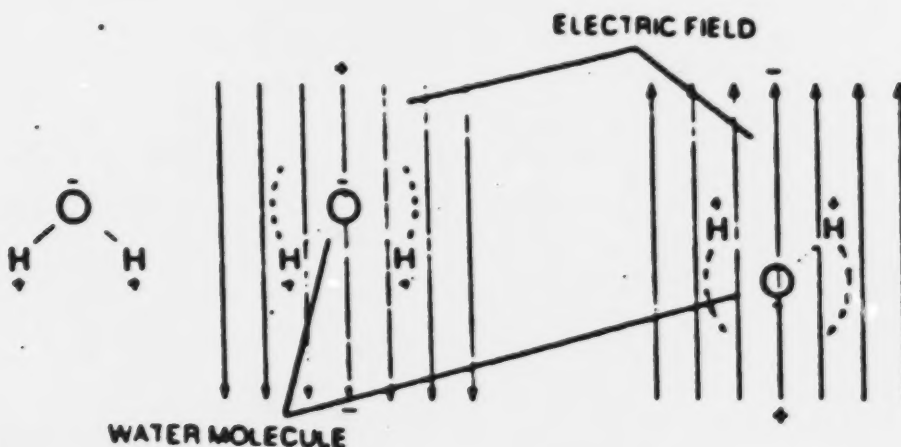
P = 480 watts

MICROWAVE OVEN



The microwave oven heats only foods that contain water. It can cook a complete meal in less than two minutes.

A water molecule consists of a negative oxygen atom with two positive hydrogen atoms. Its shape makes it a dipole which means it has a positive and a negative 'end'. When placed in an electric field the positive ends turn towards the negative end of the field and vice versa.



ELECTRICAL POWER

POWER = VOLTAGE X CURRENT

EXAMPLE: $P = 120 \text{ volts} \times 4 \text{ amperes}$

$P = 480 \text{ watts}$

TITLE: Moving Coil Ammeter

DESCRIPTION:

This transparency presents the construction and operation of the moving coil ammeter. The basic parts of the ammeter will be identified. The nature and direction of a permanent magnetic field and the production of the electromagnetic field using a coil of wire will be presented. The nature and direction of a permanent magnetic field and the production of the electromagnetic field using a coil of wire will be presented. The interaction of magnetic fields to produce a "motor action" will be presented.

SCIENCE CONCEPTS:

1. Understanding the Magnetic Fields

The interaction of fields produced by the permanent magnet and the electro-magnet provides the torque causing rotation of the coil and its attached pointer.

a. Permanent Magnet

The field strength needed is determined during research conducted during the design of each specific meter. A c-shaped permanent magnet concentrates the field between the opposing poles producing a strong, durable field with little or no force lines elsewhere along the magnet.

b. Electro-magnet

Wire is coiled around a metal ~~frame~~ which pivots on an axis between the c-shaped magnet poles. When a current is passed along the coil a magnetic field is produced. The electro-magnetic field attempts to line up with the permanent magnet field because of the torque of the magnetic force. The degree of coil rotation is determined by the strength of the induced field. The strength of the induced field is determined by the amount of current flowing along the coil.

TITLE: Moving Coil Ammeter
SCIENCE CONCEPTS (continued)

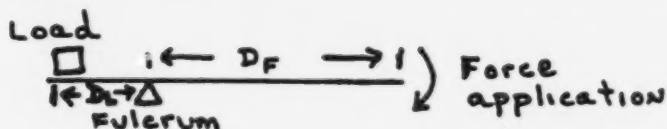
2. Understanding the influence of the Hair or Flat-coil Spring

A flat-coil spring serves to zero the pointer when current is not applied and to provide a counter or restoring torque resisting the magnetic torque produced when current is applied. The spring may also provide one leg in the circuit carrying the current to or from the coil.

3. Understanding the Coil/pointer as a Lever System

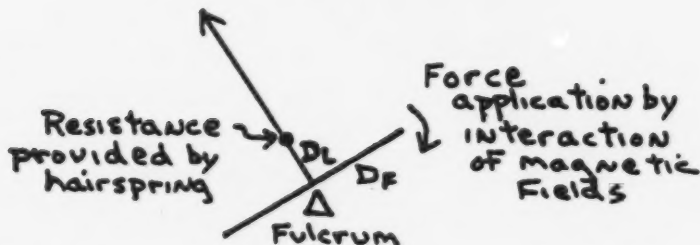
The pivoting coil/pointer may be thought of as a Class I lever system.

CLASS I LEVER SYSTEM



Fulcrum = pivot point of Coil/pointer
 Load = resisting torque of hair spring
 Force = torque of the magnetic force
 D_f = distance between Fulcrum and force
 D_l = Distance between Fulcrum and Load

The Coil/pointer as a Lever



TITLE: MOVING COIL AMMETER

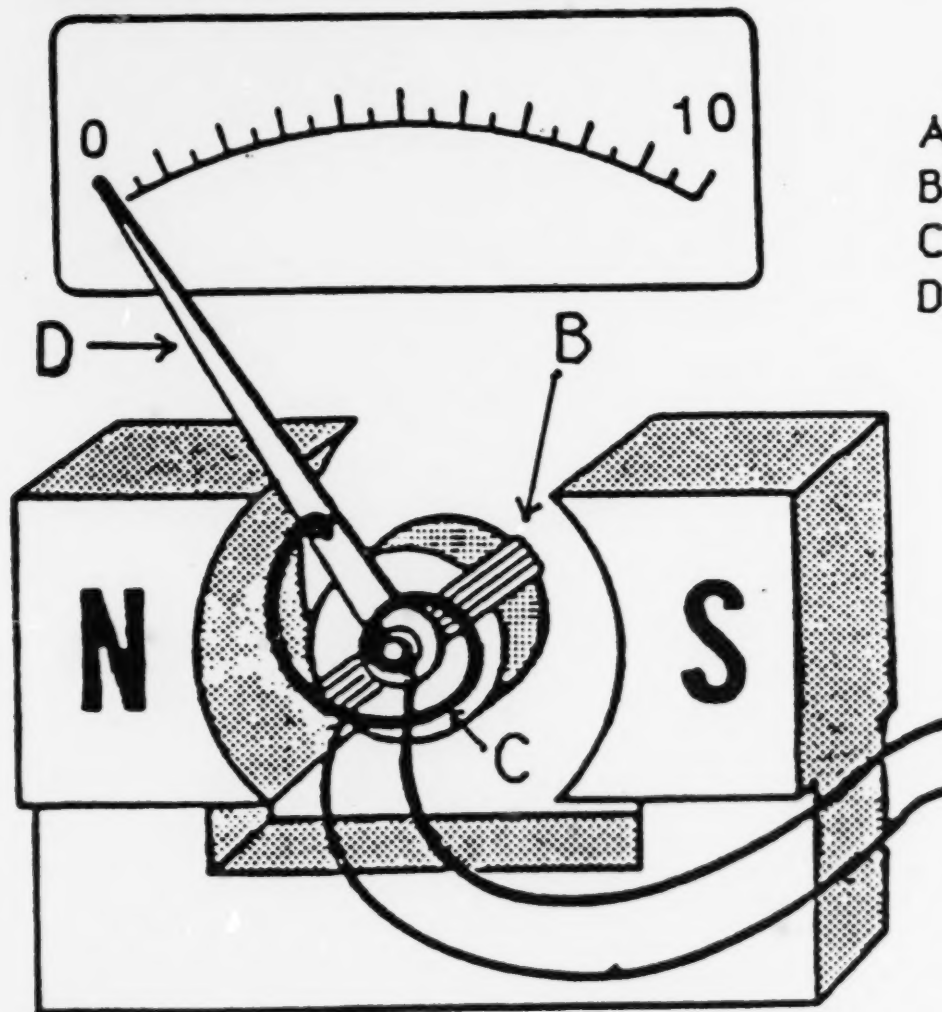
DESCRIPTION:

This transparency presents the construction and operation of the moving coil ammeter. The basic parts of the ammeter will be identified. The nature and direction of a permanent magnetic field and the production of the electromagnetic field using a coil of wire will be presented. The interaction of magnetic fields to produce a "motor action" will be presented.

MATH CONCEPTS

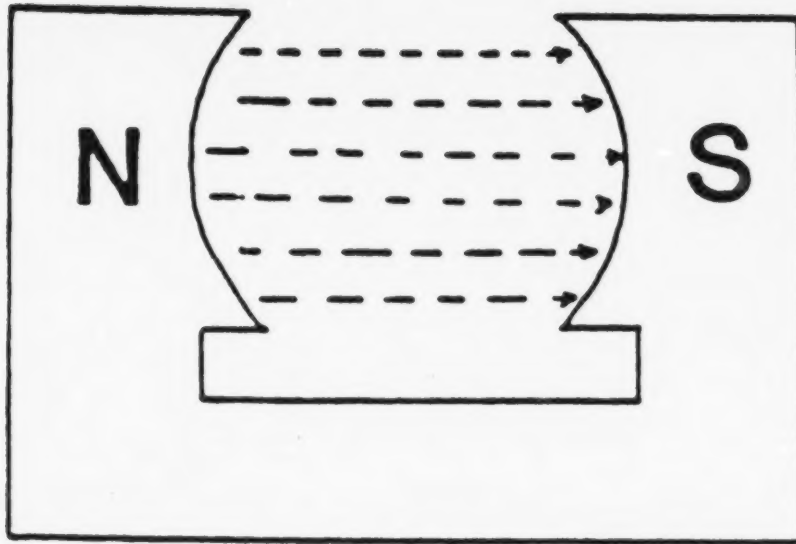
1. Reading a meter. This includes linear scales (as in the Ammeter and Voltmeter) as well as non-linear scales (as in Ohmmeters which measure resistance.)
2. Solving the formula for mechanical advantage to determine the efficiency of a machine: $MA = \frac{D_f}{D_l}$, where D_f is the distance of the force from the fulcrum and D_l is the distance of the load from the fulcrum. (An alternate formula is $MA = \frac{\text{Force Applied}}{\text{Work Accomplished}}$).
3. Interpreting Ohm's Law and solving for the other variables:
 $E = IR = R = \frac{E}{I}$ or $I = \frac{E}{R}$ where E stands for electromotive force, in volts; I, for current, in amperes; R for resistance in OHMS. This concept requires the student to be able to solve an equation for one variable in terms of others and to recognize equivalent equations.
4. Applying the formula for calculating the intensity of a field:
 $H = \frac{nI}{l}$ where nI stands for ampere-turns and l is the length of coil in meters. However, this formula yields mks (meter-kilogram-second) which must be converted to Oe (Oersteds) by multiplying the answer for H by 0.0126 since $1000 \text{ A/m} = 12.6 \text{ Oe}$.

MOVING COIL AMMETER



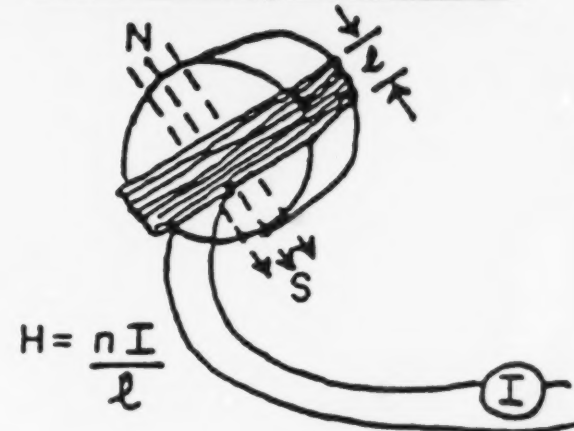
- A - Magnet
- B - Coil
- C - Spring
- D - Needle

MOVING COIL AMMETER



Permanent magnetic field is produced by a horseshoe magnet.

Electromagnetic Field



H=field intensity
n=number of turns
I=current in coil
l=length of coil

TITLE: NEWCOMEN STEAM ENGINE

CATEGORY: INNOVATION

DESCRIPTION:

THE CREATION OF THE STEAM ENGINE BY THOMAS NEWCOMEN IN THE EARLY 1700'S WAS A PRACTICAL APPLICATION OF A PRINCIPLE DISCOVERED BY DR. DENIS PAPIN IN 1680. THE NEWCOMEN ENGINE PRODUCED MOTION BY FILLING A CYLINDER WITH STEAM. THE FORCE OF THE STEAM MOVED A PISTON UPWARD, COLD WATER WAS THEN SPRAYED IN THE CYLINDER, AIR PRESSURE OUTSIDE THE CYLINDER THEN FORCED THE PISTON DOWNWARD. A ROD WAS CONNECTED TO THE PISTON. THIS ROD MOVED UP AND DOWN WHILE THE ENGINE WAS OPERATING. THE ROD OPERATED THE PUMP, WHICH DRAINED THE MINE WATER. NEWCOMEN'S STEAM ENGINE COULD HAVE BEEN MODIFIED TO SERVE MANY PURPOSES, HOWEVER IT SEEMS TO HAVE BEEN USED SOLELY FOR THE PURPOSE OF PUMPING WATER INITIALLY.

TITLE: NEWCOMEN STEAM ENGINE

CATEGORY: INNOVATION

SCIENCE CONCEPTS:

1. ENERGY IS NEEDED FOR WORK TO BE DONE.
2. WORK IS THE RESULT OF A FORCE ACTING ON A BODY AND MOVING IT THROUGH A DISTANCE. A FORCE IS DEFINED AS A PUSH OR A PULL.
3. THE KINETIC MOLECULAR THEORY STATES THAT ALL MATTER IS MADE OF MOLECULES. AS THE TEMPERATURE OF THE MOLECULES INCREASES SO DOES THE MOVEMENT OF THE MOLECULES. AS THE MOVEMENT OF THE MOLECULES INCREASES SO DOES THE PRESSURE INSIDE THE CLOSED CONTAINER.
4. THE BOILING POINT OF WATER IS 100°C OR 212°F .
5. AS WATER REACHES ITS BOILING POINT THE PROCESS OF EVAPORATION BEGINS. AT THIS POINT THE WATER MOLECULES CHANGE FROM A LIQUID TO A GAS.
6. AS WATER VAPOR IS COLLECTED AND COOLED, ANOTHER PROCESS BEGINS, CONDENSATION. AT THIS POINT THE MOLECULES CHANGE FROM A GAS TO A LIQUID.
7. AS A GIVEN AMOUNT OF WATER BOILS AND CHANGES INTO STEAM, THE VOLUME OF THE STEAM IS 1700 TIMES GREATER THAN THE VOLUME OF THE WATER.
8. IF STEAM CONDENSES IN A CLOSED CONTAINER, A PARTIAL VACUUM IS CREATED.
9. ENERGY CONVERSION OCCURS AS ENERGY IS BEING TRANSFERRED FROM HEAT TO MECHANICAL ENERGY.

TITLE: NEWCOMEN STEAM ENGINE

CATEGORY: INNOVATION

MATH CONCEPTS:

1. $WORK = FORCE \times DISTANCE$

FORCE CAN BE MEASURED IN NEWTONS OR POUNDS,

DISTANCE CAN BE MEASURED IN METERS OR FEET,

WORK THEN IS EXPRESSED IN A UNIT CALLED A NEWTON-METER OR A FOOT-POUND.

2. ANOTHER WAY TO EXPRESS A UNIT OF WORK OR ENERGY IS CALLED A JOULE (J).

JOULE (J) = NEWTON-METER (N-M)

3. $PRESSURE = \frac{FORCE}{AREA}$

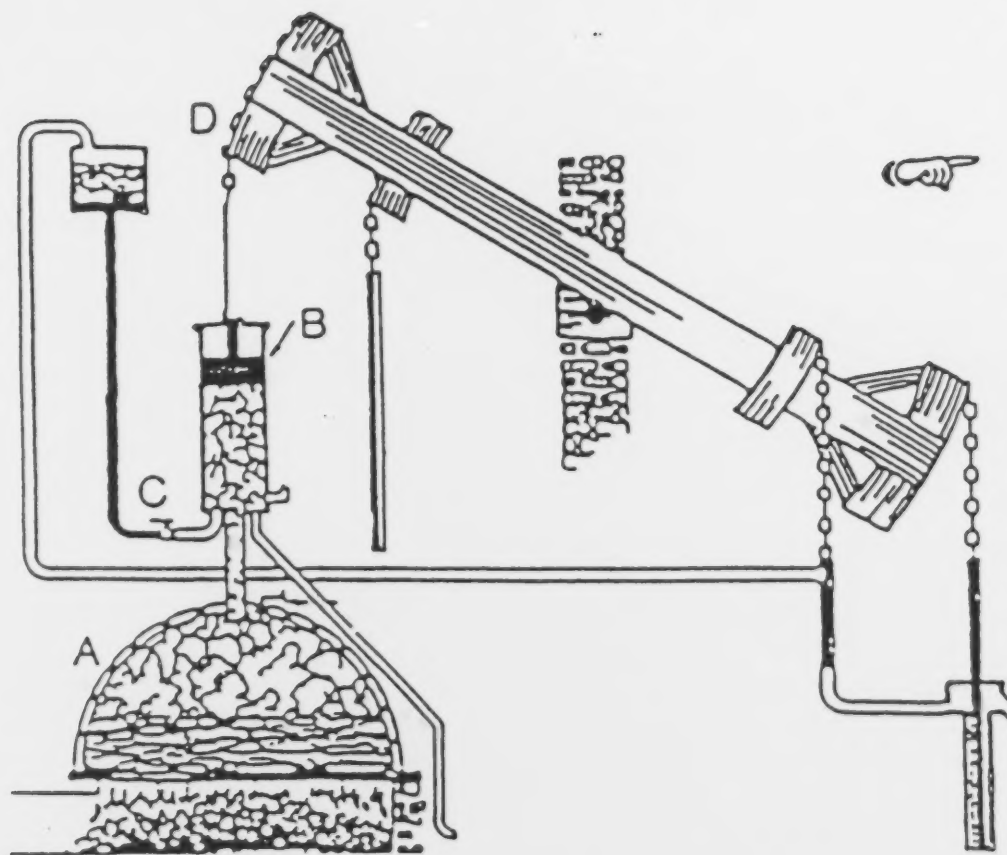
FORCE CAN BE MEASURED IN GRAMS OR POUNDS,

AREA CAN BE MEASURED IN CENTIMETERS² OR INCHES².

FORMULA FOR FINDING AREA OF A CIRCULAR SURFACE IS:

$$A = \pi r^2$$

NEWCOMEN STEAM ENGINE 1705



A PRACTICAL ENGINE
USING STEAM TO
HELP US WORK

INVENTOR:
THOMAS NEWCOMEN

NEWCOMEN STEAM ENGINE

1705

A BOILER

KINETIC MOLECULAR THEORY:
INCREASED MOVEMENT OF MOLECULES
AS TEMPERATURE INCREASES

EVAPORATION: $\text{H}_2\text{O} \xrightarrow{\Delta} \text{H}_2\text{O} \uparrow$

B CYLINDER & PISTON

PRESSURE (psi) = $\frac{\text{FORCE}}{\text{AREA}}$

C COLD WATER VALVE

CONDENSATION:

WATER VAPOR COOLS $\rightarrow \text{H}_2\text{O}(\text{liquid})$

AS STEAM CONDENSES IN A CLOSED CONTAINER
A PARTIAL VACUUM IS CREATED

D BEAM

WORK (ft. lbs.) = FORCE x DISTANCE

TRANSFER OF ENERGY:

HEAT ENERGY $\rightarrow$ MECHANICAL ENERGY

TITLE: OHM'S LAW

CATEGORY: INNOVATION

DESCRIPTION:

George Ohm (1787-1854) discovered a mathematical relationship between voltage, current and resistance in an electrical circuit. He found that the current in a circuit is affected by the electromotive force (EMF) and resistance. Ohm's Law says that the electric current in a circuit is equal to the EMF divided by the resistance.

OHM'S LAW

$$\text{electric current (amperes)} = \frac{\text{electromotive force (volts)}}{\text{resistance (ohms)}}$$

SCIENCE CONCEPTS:

1. Ohm's Law predicts what will happen to the electric current.
2. Electricity can be thought of as a flow of negative electrical charges (electrons).
3. Electromotive force (EMF) is the push of electrons through a conductor.
4. Electric current in a circuit is equal to the EMF divided by the resistance.
5. Resistance is a measure of how difficult it is to move electrons through a conductor.
6. Resistance is measured in ohms.
7. Different materials have different resistances.
8. A conductor that has a large resistance for its size is called a resistor.
9. An insulator has an extremely high resistance.
10. Resistance of a conductor depends on its thickness, its length, the material it is made of and its temperature.
11. The power source uses chemical energy (or some other form of energy) to force electrons from one side (terminal) to the other.

TITLE: OHM'S LAW

CATEGORY: INNOVATION

MATHEMATICAL CONCEPTS:

1. Ohm's Law $I = \frac{V}{R}$

I = electric current (ampere)
V = electromotive force (volt)
R = resistance (ohms)

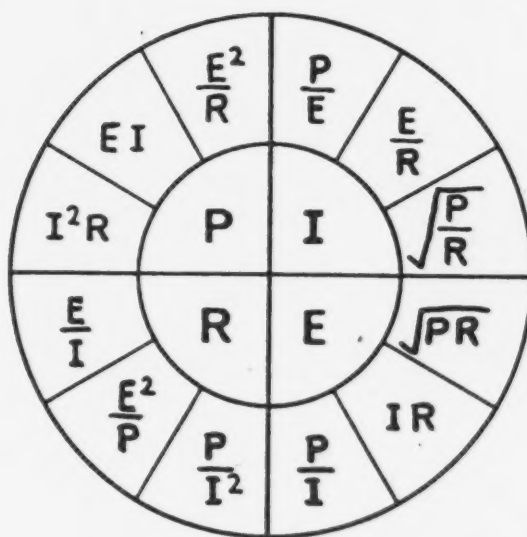
2. Use proportions to solve for V, I or R given the other 2.
3. Multiplication of decimals.
4. Division of decimals.
5. Use of calculator.

OHM'S LAW

THE ELECTRIC CURRENT IN A CIRCUIT IS EQUAL TO THE EMF(VOLTS)
DIVIDED BY THE RESISTANCE.

$$I = \frac{V}{R}$$

$$\text{ELECTRIC CURRENT(AMPERES)} = \frac{\text{ELECTROMOTIVE FORCE(VOLTS)}}{\text{RESISTANCE(OHMS)}}$$



$$I = 9v / 220\text{OHMS} = .041 \text{ AMP!}$$

EQUATIONS BASED
ON OHM'S LAW

P = Power in Watts

I = Intensity of Current
in Amperes

R = Resistance in Ohms

E = Electromotive Force
in Volts

ELECTROMOTIVE FORCE

ELECTRIC CURRENT

RESISTANCE

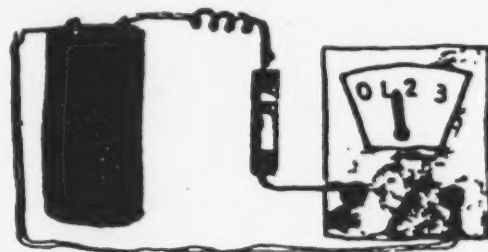
POWER

V VOLT

I AMPERE

R OHM

P POWER



TITLE: Overshot Water Wheel

CATEGORY: Innovation

DESCRIPTION:

The water wheel sometimes called a gravity wheel was a simple mechanical device that effectively converted the linear motion of flowing water into useful rotary motion that could be used for grinding grain and many other purposes. The horizontal wheel was used where conditions were suitable. Its blades had to be arranged in any of several ways, exposed and at an angle to the hub, or protected by a rim, or fitted with buckets. The horizontal wheel was best suited to a small volume of water flowing at a fairly high velocity. Inside the mill the gearing consisted of a pit wheel on the shaft of the horizontal water wheel. The pit wheel was geared to a smaller wheel, the wallower, giving an increase of speed.

SCIENCE CONCEPTS:

1. WATERPOWER IS A RENEWABLE SOURCE OF ENERGY.

2. WATER CYCLE-

EVAPORATION OF WATER FROM THE EARTH'S SURFACE COLLECTS IN THE ATMOSPHERE AS VAPOR.

CONDENSATION OCCURS IN THESE CLOUDS OF VAPOR, WATER FALLS BACK TO THE SURFACE OF THE EARTH.

3. WORK IS THE RESULT OF A FORCE ACTING ON A BODY AND MOVING IT THROUGH A DISTANCE.

4. ENERGY IS NEEDED FOR WORK TO BE DONE.

5. ENERGY CONVERSION OCCURS AS ENERGY IS BEING TRANSFERRED FROM KINETIC TO MECHANICAL ENERGY.

6. SIMPLE MACHINE- A DEVICE THAT HELPS YOU DO WORK BY INCREASING FORCE, INCREASING SPEED, OR CHANGING THE DIRECTION OF THE FORCE.

WHEEL AND AXLE- A SIMPLE MACHINE THAT IS A TYPE OF LEVER.

LEVER AND FULCRUM- A BAR OR BOARD THAT IS FREE TO PIVOT ABOUT A FIXED POINT CALLED THE FULCRUM.

GEARS- A KIND OF WHEEL-LIKE MACHINE THAT ACTS LIKE A LEVER.

7. FRICTION- A FORCE THAT ACTS TO SLOW DOWN A MOVING OBJECT THAT IS PASSING THROUGH OR AGAINST A MATERIAL. A FORCE IS A PUSH OR A PULL.

TITLE: OVERSHOT WATER WHEEL

CATEGORY: INNOVATION

MATH CONCEPTS:

1. WORK (FT. LBS.) = FORCE x DISTANCE

2. MULTIPLICATION OF RATIONAL NUMBERS

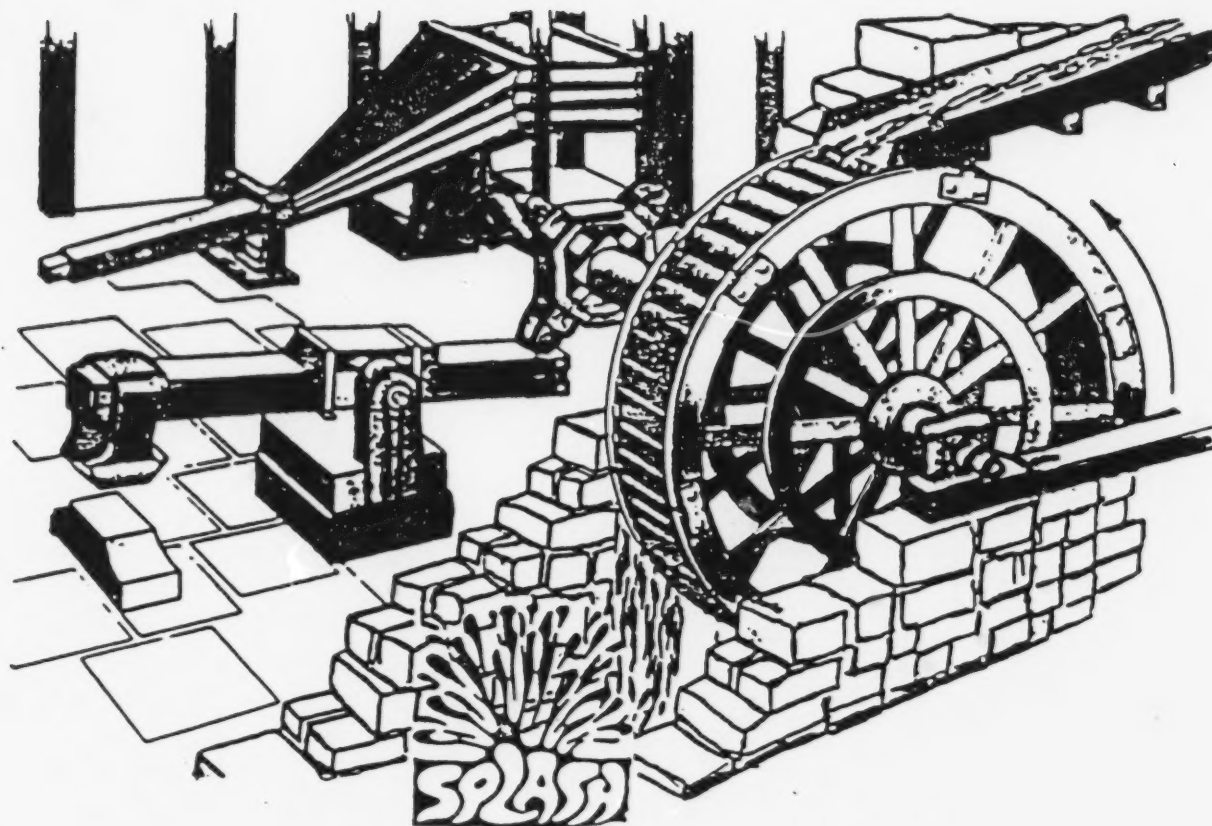
3. $P = Q \times H$

POTENTIAL WATER POWER: VOLUME OF WATER FLOWING PAST SITE
PER UNIT OF TIME x FALL OF WATER
(DISTANCE FROM SITE TO TOP OF WHEEL)

4. RATIOS

5. EFFICIENCY (%) = $\frac{\text{OUTPUT}}{\text{INPUT}} \times 100$

OVERSHOT WATER WHEEL



255

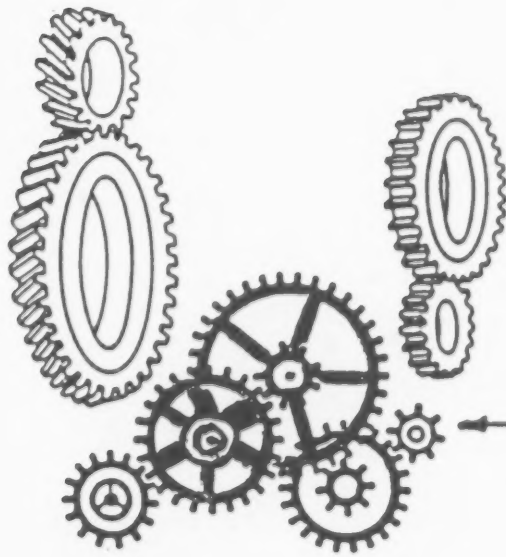
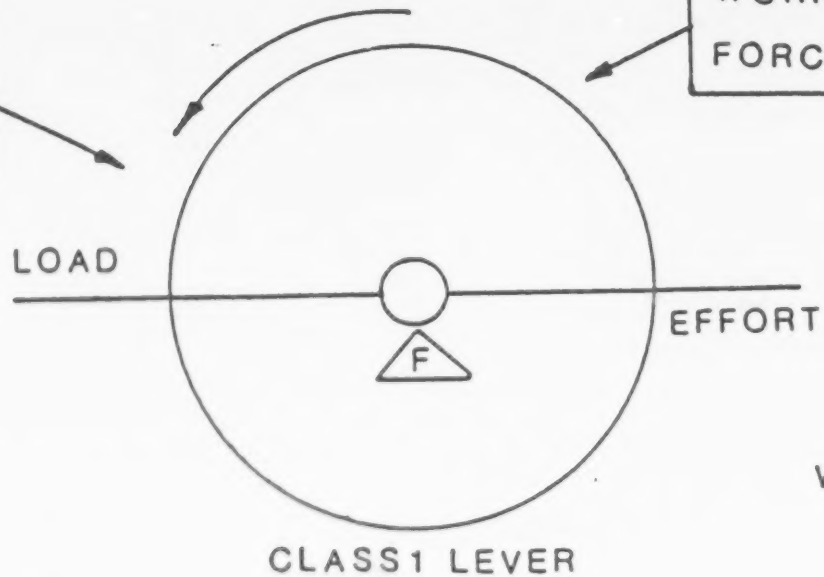
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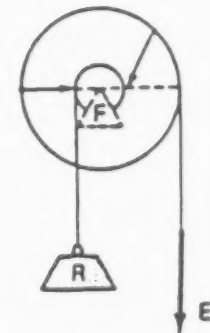
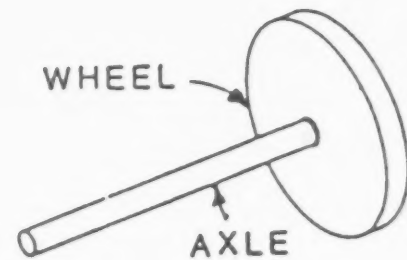
OVERSHOT WATER WHEEL

$$MA = \frac{\text{LOAD}}{\text{EFFORT}}$$

$$\text{WORK (ft. lbs.)} = \text{FORCE} \times \text{DISTANCE}$$



GEARS CONTROL MOTION



Title: Parabolic Furnace

Description:

The study of the parabolic furnace will encompass many of the concepts found in the family of conic sections, namely the parabola. In addition, the scientific concept of energy transformation will be included in this study.

Science Concepts:

1. Energy is the ability to do work.

where $W = Fd$

W = work

F = force

d = distance

types:

a. Kinetic Energy - energy of motion

where $K.E. = 1/2 mv$

K.E. = Kinetic Energy

Energy

m = mass

v = speed

b. Potential Energy - energy of position in a force field

where $P.E. = mgh$

P.E. = Potential energy

m = mass

$g = 9.8 \text{ m/s}^2$

(acceleration due to gravity)

c. Rest Energy - energy by virtue of mass form

2. One form of energy can be transformed into another.

ex. light (radiant) energy ---> heat (thermal) energy
---> electrical energy (via a thermal couple)

3. Light can demonstrate wave and particle properties

a. Wave Theory of Light - light is a succession of waves

DIAGRAM



λ = wavelength - distance from peak to peak of a light wave. Therefore, one color of light differs from another by λ .

b. Particulate Theory of Light - light is a stream of high energy particles (photons).

TITLE: Parabolic Furnace

DESCRIPTION:

The study of the parabolic furnace will encompass many of the concepts found in the family of conic sections, namely the parabola. In addition, the scientific concept of energy transformation will be included in this study.

MATH CONCEPTS:

- 1 Basic terms associated with the parabola include:

Parabola: The set of points equidistant from a fixed point (focus) and a fixed line (directrix).

Axis of Symmetry: The "imaginary" line which passes through the focus and the vertex.

Focus: The point of convergence of the reflected light rays which enter parallel to the axis of symmetry.

Vertex: The midpoint of a line segment extending from the focus perpendicular to the directrix.

Focal Length: The distance from the vertex to the focus.

2. General diagram of the parabola:



3. Method of sketching a parabola using the following materials:

- a.) A straight-edge
- b.) A compass
- c.) A T-square

- i. Mark off any line on the plywood (possibly the edges).
- ii. Draw a line, using the T-square, perpendicular to the directrix line drawn previously.
- iii. Select the focus on the line drawn in step (ii). Note: The further the focus is from the directrix, the more "closed" the parabola will be. The opposite is true as well.
- iv. Use the definition of the parabola as the set of points equidistant from a fixed line to construct a parabola. Let the distance between focus and the directrix be 2.0 inches, for example. Then

draw a line parallel to the directrix at some arbitrary say 3.0 inches. Then with the same 3.0 inch radius and point F as center, draw arcs intersecting that line in two points. These points lie on the parabola. Additional points may be located by increasing the distance of the line from the directrix and increasing the compass setting accordingly. Note: The vertex is half-way between the directrix and the focus lying on the axis of symmetry. Alternately, the parabola may be constructed using the equation $Y = aX + bX + c$. The X values and their corresponding Y values may be graphed to create a pattern which can then be laid out on the material to be cut. Note: When choosing value 'a' the instructor should remember the following rule: The larger 'a' is, the more closed the parabola. The smaller 'a' is, the more flat the parabola.

PARABOLA SPECIFICATIONS:

GENERAL EQUATION: $Y = A \times X^2$

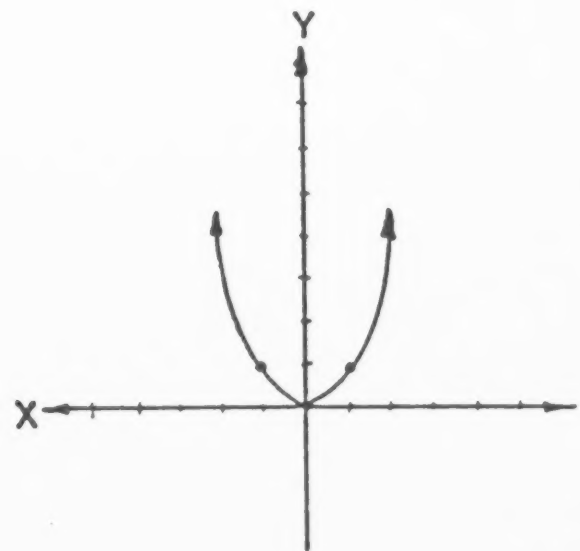
FOCAL LENGTH: $FL = \frac{1}{4 \times A}$

NOTE: If the value of 'A' is a large number,
the parabola will be more closed.

If the value of 'A' is a small number,
the parabola will be more open.

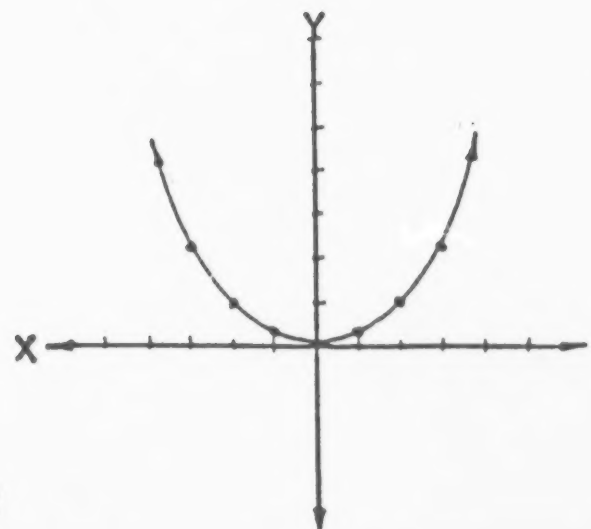
$$Y = 1 \times X^2$$

X	Y
0	0
1	1
2	4
-1	1
-2	4



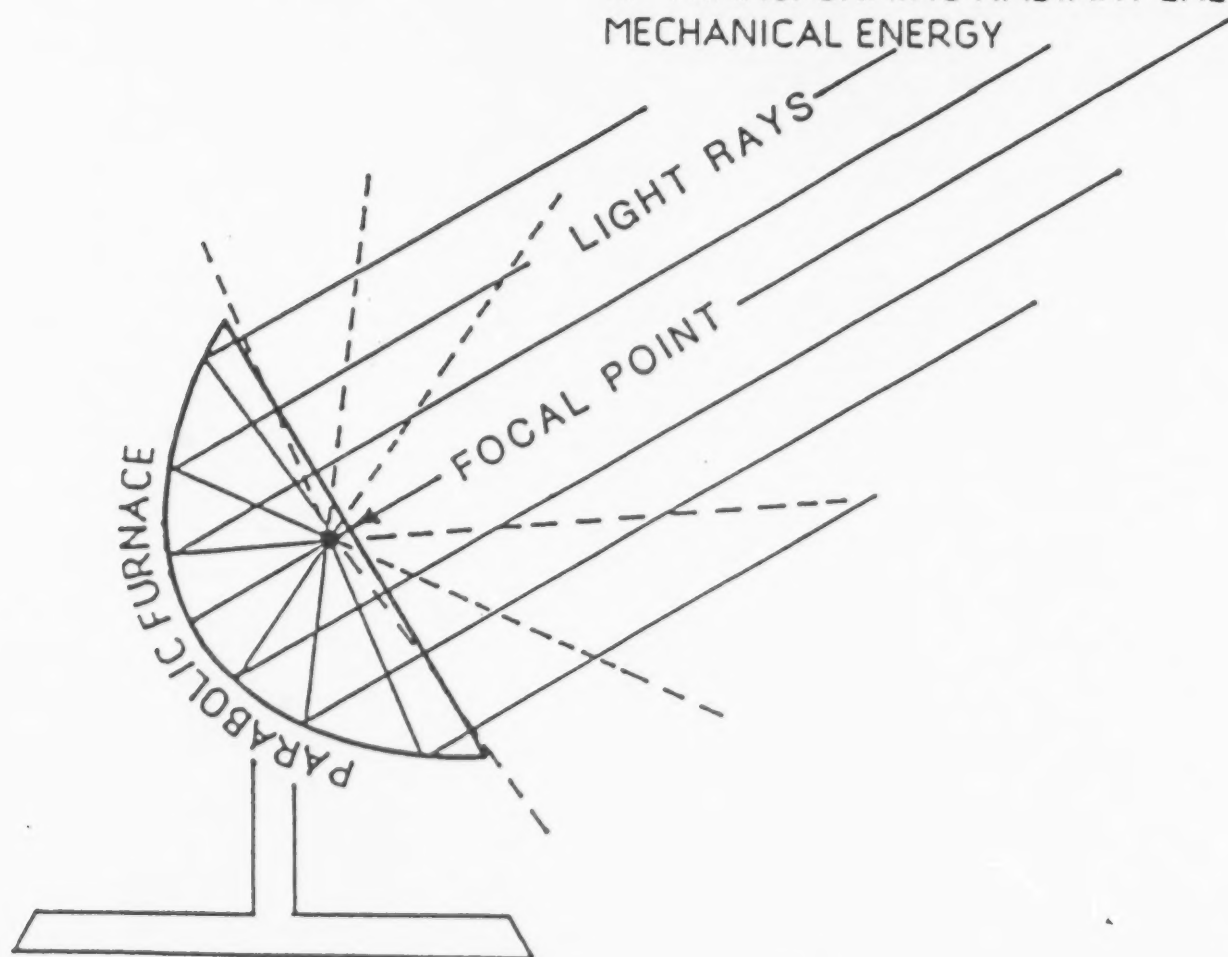
$$Y = .25 \times X^2$$

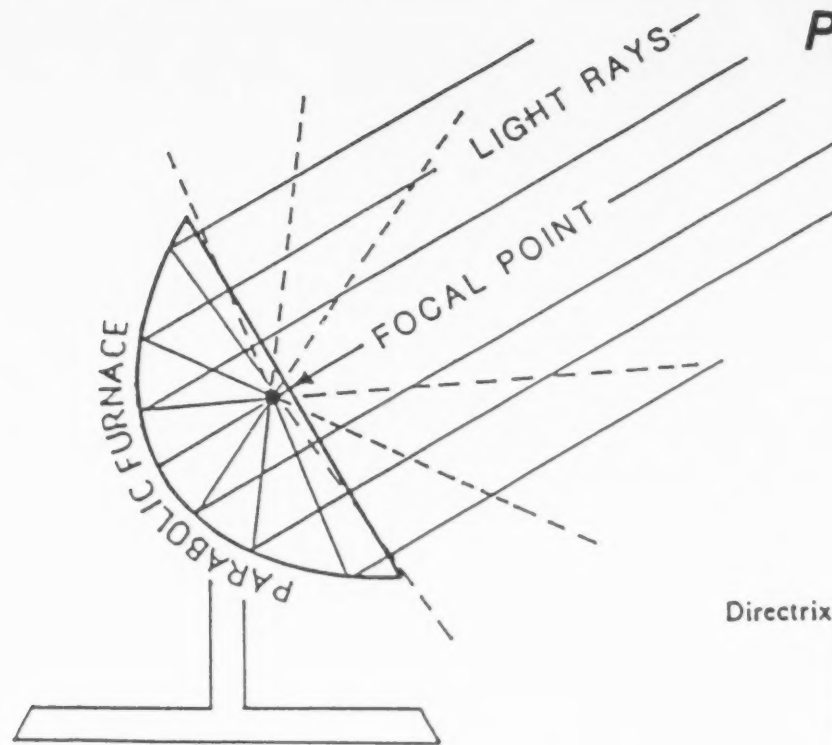
X	Y
0	0
1	.25
2	1
-1	.25
-2	1



PARABOLIC FURNACE

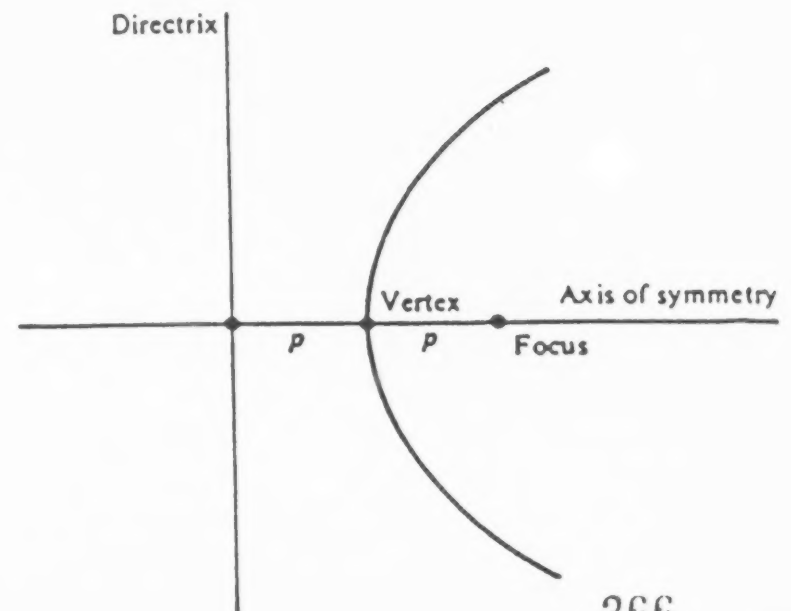
A MECHANICAL DEVICE THAT IS CAPABLE
OF TRANSFORMING RADIANT ENERGY INTO
MECHANICAL ENERGY





PARABOLIC FURNACE

A *PARABOLA* IS THE SET OF POINTS EQUIDISTANT FROM A FIXED POINT, THE *FOCUS*, AND A FIXED LINE, THE *DIRECTRIX*.



TITLE: PARALLEL CIRCUITRY

CATEGORY: SYSTEM

DESCRIPTION:

A parallel circuit has 2 or more loads placed side by side. The full voltage is applied across each of the loads, even though the loads are in operation from the same source. For all practical purposes, they are separate circuits. Therefore, the other loads in the circuit will not be affected and will continue to operate when one of the loads is not operational. Parallel circuits permit individual control and independent action.

SCIENCE CONCEPTS:

1. Electricity follows a path called an electric circuit.
2. Electricity can be thought of as a flow of negative electrical charges (electrons).
3. Electromotive force (EMF) is the push of electrons through a conductor.
4. An electric current always moves from a negative terminal to a positive terminal.
5. A parallel circuit has more than one path for the electricity to follow.
6. When one part of a parallel circuit stops functioning, the other part will work.
7. The amount of current may be different in different parts of the circuit.
8. Electric current is measured in amperes.
9. To measure the current in one part of the circuit, connect an ammeter in series with that part of the circuit.
10. In a parallel circuit, adding devices provides additional paths for the current and decreases the total resistance.

TITLE: PARALLEL CIRCUITRY

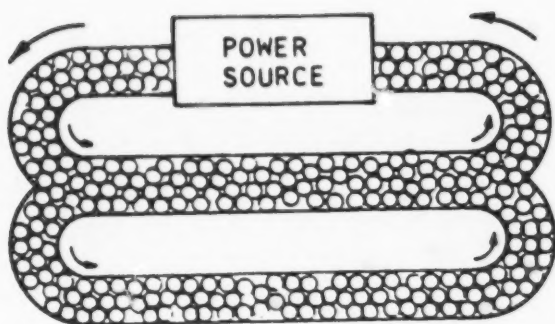
CATEGORY: SYSTEM

MATHEMATICAL CONCEPTS:

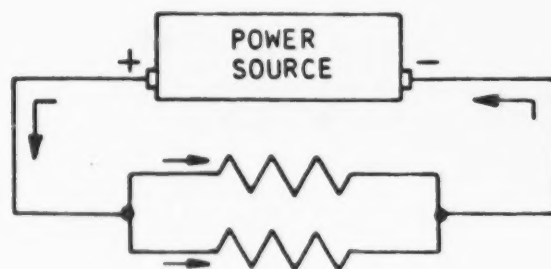
1. Ohm's Law $R = \frac{E}{I}$
R = Resistance
E = EMF in volts
I = Intensity of current in amperes
2. 2-leg circuit $R_E = \frac{R_1 \times R_2}{R_1 + R_2}$ R_E = Resistance in parallel circuit
 R_1, R_2 = Individual resistance
3. 3 or more legged circuit
$$\frac{1}{R_E} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} \dots$$
4. Solve ratios and proportions
5. Determine reciprocals
6. Multiplication of decimals
7. Division of decimals
8. Order of operations
9. Use of calculator

PARALLEL CIRCUITRY

PARALLEL CIRCUIT: A CIRCUIT THAT HAS MORE THAN ONE PATH FOR THE ELECTRICITY TO FOLLOW



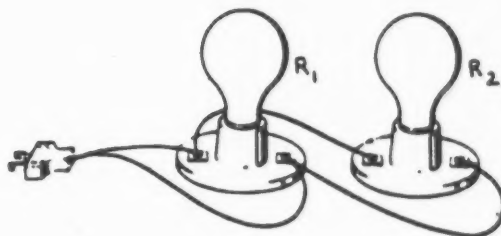
HAVING TWO OR MORE CIRCUIT PATHS CAUSES GREATER INTENSITY OF MARBLE FLOW FROM THE SOURCE.



TOTAL RESISTANCE OF RESISTORS IN PARALLEL IS LESS THAN THE SMALLER RESISTOR.

OHM'S LAW

$$R = \frac{E}{I}$$



$$R_{EQUIV} = \frac{R_1 \times R_2}{R_1 + R_2}$$

TITLE: PASSIVE SOLAR HEATING

CATEGORY: RESEARCH AND EXPERIMENTATION

DESCRIPTION:

Passive solar heating refers to the methods by which solar energy is used to heat a dwelling without using energy-consuming mechanisms to absorb, store, or transfer the solar energy. In order to fully utilize this free energy, architects and builders must have knowledge of the characteristics of building materials, earth-sun relationships, and the mathematical concepts involved.

SCIENCE CONCEPTS:

1. Light energy striking a surface may be reflected, transmitted, or absorbed.
2. Usually, when light energy is absorbed, it is converted to heat.
3. Conduction is the transfer of heat from molecule to molecule by direct contact.
4. Convection is the transfer of heat in fluids by the movement of molecules.
5. Radiation is the transfer of heat through space which does not require a medium.
6. Insolation refers to the amount of solar radiation striking a given surface at a given time. It is dependent upon latitude, season, time of day and meteorologic conditions.
7. In order to operate efficiently, a solar home must have sufficient thermal storage mass to absorb excess heat during sunny hours and thus avoid overheating of the living space, and to maintain comfortable temperatures throughout the night.
8. Insulation refers to the resistance to heat transfer of a material. A good insulator has a reflective surface to reduce absorptance and much dead air space to reduce conduction and convection.
9. In order to properly orient and design a solar home, one needs to consider the position of the sun at various times of the day and year. This is determined by using sun path diagrams.
10. Azimuth refers to the position, in degrees, of the sun, east or west of true south.
11. Altitude refers to the sun's position, in degrees, above the horizon.
12. Solar noon is when the sun is at its greatest altitude for any given day. It will be directly south and, therefore, have an azimuth of 0.
13. To determine solar noon altitude for June 21 use the formula, $A = 90 - (L - 23\frac{1}{2})$; for December 21 use the formula, $A = 90 - (L + 23\frac{1}{2})$ where A = solar noon altitude and L = your latitude.

TITLE: PASSIVE SOLAR HEATING

CATEGORY: RESEARCH AND EXPERIMENTATION

MATHEMATICAL CONCEPTS:

1. British Thermal Unit--the amount of heat required to raise the temperature of 1 pound of water 1 Fahrenheit.
2. Conduction Heat Loss--loss of heat that occurs when heat passes through the exterior elements of a building.
3. Degree Day--a measure of heating need determined by subtracting an average daily temperature below 65 Fahrenheit from the base number 65.
4. Design Temperature--the minimum above which the outdoor temperature will remain 97.5% of the time.
5. Infiltration Heat Loss--loss of heat that occurs when cold outside air enters a building through cracks and must be heated.
6. Peak Heat Load--a building's maximum rate of hourly heat loss on a cold night when the outside temperature is the same as the design temperature.
7. R-Value--a measure of a given material's resistance to heat loss.
8. Temperature Difference--a figure used in calculating heat loss. It is determined by subtracting the design temperature from the indoor thermostat setting.
9. Thermal Efficiency--a quality of a building in which there is minimal heat loss in winter and heat gain in summer, making possible a lower expenditure of energy for heating and cooling.
10. U-Value--a measure of heat loss through a particular building component when outside air is 1 Fahrenheit colder than inside air, expressed in terms of Btu's per square foot per hour.
11. To calculate conduction heat loss you will need to add the heat loss found through all exterior parts of the house. Ex. walls, floors, ceilings, windows)

$$\text{Conduction Heat Loss} = \frac{\text{Part of House}}{\text{U-Value}} \times \frac{\text{Area}}{\text{Sq. Ft.}} \times \frac{\text{Temperature}}{\text{Difference}}$$

The U-value for various materials may be obtained from various tables.

Area = Length x Width

Temperature Difference = 65 - Design Temperature

MATHEMATICAL CONCEPTS:

(CONTINUED)

12. Infiltration Heat Loss is an estimated value which may be calculated using the following formula:

$$IHL = .018 \times \frac{3}{4} \times \text{Volume} \times \text{Temperature Difference}$$

$$\text{Volume} = \text{Length} \times \text{Width} \times \text{Height}$$

13. The peak heat load is the sum of conduction and infiltration heat losses.

$$\text{Peak Heat Load} = \text{Conduction Heat Loss} + \text{Infiltration Heat Loss}$$

14. To calculate heat loss for a year (which, among other things, will let you estimate your conventional heating bill), you must first determine the loss for each Degree Day, or Btu/DD

$$\text{Btu/DD} = \frac{\text{Btuh (Peak Heat Load)} \times 24 \text{ (hrs./day)}}{\text{Temperature Difference}}$$

$$\text{Total annual heat loss} = \text{Btu/DD} \times \text{DD/yr.}$$

15. Internal heat gain in a home is the amount of heat given off by objects such as the stove, water heater, occupants, etc. The approximate internal heat gain for a family of four is 20,000,000 Btu/yr.

16. Net Heat Loss (Btu/yr.) = Total Heat Loss (Btu/yr.) - Internal Heat Gain (Btu/yr.)

17. Net thermal efficiency = $\frac{\text{Net Heat Loss (Btu/yr.)}}{\text{DD/yr.} \times \text{sq. ft.}}$

The DD/yr. is a value calculated for various regions of the country and may be found at any oil distributorship.

PASSIVE SOLAR HEATING

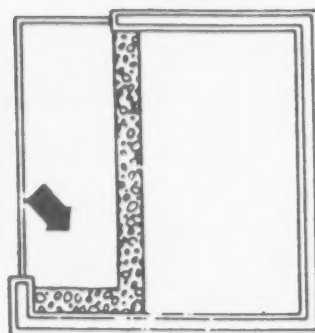
Thermal Wall Masses



MATH CONCEPTS

Conduction Heat Loss
Infiltration Heat Loss
Peak Heat Load
Degree Day
Annual Heat Loss
Internal Gain
Net Heat Loss
Net Thermal Efficiency

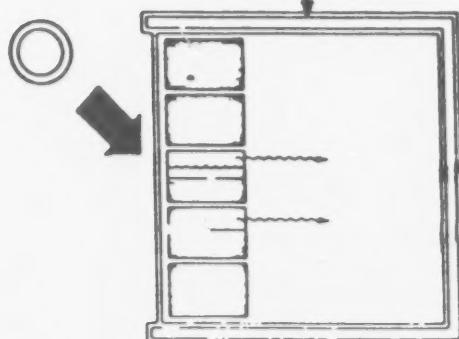
Concrete Wall



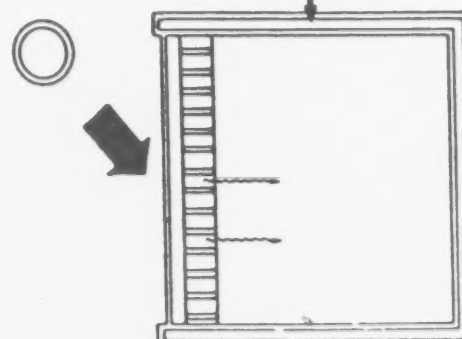
SCIENCE CONCEPTS

Heat Transfer
Energy Conversion
Insolation
Seasonal Variations
Effects Of Latitude
Thermal Storage
Insulation
Sun Path Diagram

Water Wall



Brick Wall



TITLE: THE RELATIONSHIP OF SPECIFIC CIRCUIT VOLTAGE CHANGES TO BOYLE'S AND CHARLES' GAS LAWS

CATEGORY: PROBLEM SOLVING

DESCRIPTION:

Changes in pressure and temperature can be measured through a transducer. Pressure is inversely proportional to resistance through electrostatic foam. Temperature is directly proportional to resistance through a thermistor. The combined effect of pressure and temperature may be measured through transducers in a series circuit. Measuring the voltage across a series combination of electrostatic foam and thermistor will make voltage inversely proportional to pressure changes and directly proportional to temperature changes.

This specific circuit relates changes in temperature and pressure in terms of a voltage. While it is important to understand a transducer's function, the student should also compare the circuit's function to Boyle's and Charles' Gas Laws. Voltage is affected in the same way that volume is affected in the gas laws. Boyle's Law shows that pressure varies inversely to volume, holding temperature constant. Charles' Law shows that temperature varies directly to volume, holding pressure constant.

SCIENCE CONCEPTS:

1. A transducer is a device that converts some sort of signal from one form of energy to another.
2. The thermistor is a transducer whose resistance is directly proportional to temperature.
3. Electrostatic foam acts as a transducer for pressure, where pressure is inversely proportional to resistance.
4. Boyle's Law states that when temperature remains constant, the volume of a gas is inversely proportional to the pressure applied to it.
5. Charles' Law states that when pressure remains constant, the volume of a gas is directly proportional to its temperature.
6. The voltage/resistance relationship in a specific electronic circuit is analogous to the volume/pressure/temperature relationship found in Boyle's and Charles' Gas Laws.
7. In a series circuit the voltage distribution is directly proportional to the resistance distribution.

TITLE: THE RELATIONSHIP OF SPECIFIC CIRCUIT VOLTAGE CHANGES TO BOYLE'S AND CHARLES' GAS LAWS

CATEGORY: PROBLEM SOLVING

MATHEMATICAL CONCEPTS:

1. Direct and Inverse Proportions

Thermistor: $R \propto T$ (Direct Proportion)

Where R = Resistance
 T = Temperature

Electrostatic Foam: $P \propto \frac{1}{R}$ (Inverse Proportion)

Where P = Pressure
 R = Resistance

2. Boyle's Law:

(Constant Temperature) $\frac{V_1}{V_2} \propto \frac{P_2}{P_1}$

Where V = Volume
 P = Pressure

3. Charles' Law:

(Constant Pressure) $\frac{V_1}{V_2} \propto \frac{T_1}{T_2}$

Where V = Volume
 T = Pressure

4. Component Voltage is directly proportional to component resistance a series circuit.

$\frac{R_1}{R_2} \propto \frac{VR_1}{VR_2}$

Where R_1 = Component Resistor One
 R_2 = Component Resistor Two
 VR_1 = Voltage Across Resistor One
 VR_2 = Voltage Across Resistor Two

= THERMISTOR
 = ELECTROSTATIC FOAM
 = VOLTMETER
 R = RESISTANCE
 = VARIABLE RESISTOR

= TERMINAL
 = CONDUCTOR JUNCTION
 = GROUND
 V = VOLTAGE

SCIENCE AND MATH CONCEPTS

5. BOYLE'S LAW: $\frac{V_1}{V_2} = \frac{P_2}{P_1}$

6. CHARLES' LAW: $\frac{V_1}{V_2} = \frac{T_1}{T_2}$

- $$\frac{R_1}{R_2} = \frac{VR_1}{VR_2}$$

TITLE: RESISTOR

CATEGORY: INNOVATION

DESCRIPTION:

A resistor is an electrical device having a definite amount of resistance concentrated in a small place to provide a definite, required amount of opposition to current in a circuit. The most common resistors are the carbon composition type. It is made of fine particles of carbon or graphite which are mixed with fine particles of an insulating material, molded together and enclosed in a plastic case. The nature of the mixture depends on the resistance desired. Carbon resistors are usually rated from 2.2 ohms to 22m ohms.

SCIENCE CONCEPTS:

1. Resistance is the measure of how hard or easy it is for electric current to move through a material.
2. Conductors have a low resistance and insulators have a high resistance.
3. Resistance of a wire depends on its length, its thickness, the material it is made of and its temperature.
4. Resistance is measured in ohms.
5. The thinner the wire the greater the resistance, conversely the thicker the wire the lower the resistance.
6. The resistance in ohms of a resistor can be read from its colored bands.
7. Resistance is the basis for the generation of heat.
8. Resistors are used to control the flow of electrons.
9. Resistors are used to insure that the proper voltage reaches a particular device.
10. Heat causes electrons to be forced loose from their atoms. In other materials, such as copper, electrons may be easily forced to drift even at room temperature.

TITLE: RESISTOR

CATEGORY: INNOVATION

MATHEMATICAL CONCEPTS:

Calculate the ohm value of a resistor using the formula:

$$O = (10B_1 + B_2) \times 10^M$$

O = Ohm Value

B₁ = Band 1

B₂ = Band 2

M = Multiplier

1. Determination of place values.
2. Multiplication of decimals.
3. Order of operations.
4. Working with subscripted variables.
5. Working with exponentiated numbers.

RESISTOR

A RESISTOR IS A DEVICE USED TO PROVIDE A DEFINITE, REQUIRED AMOUNT OF OPPOSITION TO CURRENT IN A CIRCUIT.



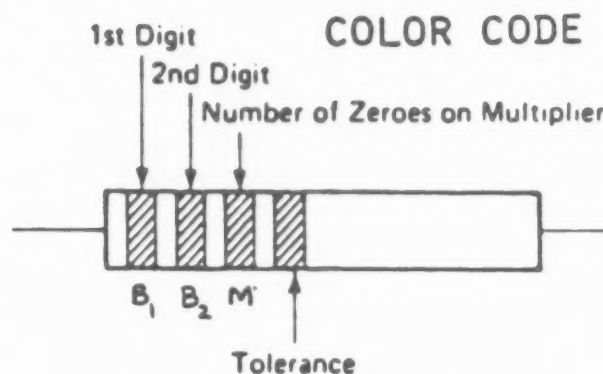
RESISTOR SYMBOL



COMPOSITION RESISTOR
CARBON OR GRAPHITE

DETERMINERS OF RESISTANCE

1. ELEMENTAL STRUCTURE
2. LENGTH OF MATERIAL
3. DIAMETER OF MATERIAL
4. TEMPERATURE OF MATERIAL



$$\text{OHM VALUE} = (10B_1 + B_2) \times 10^M$$

Color Code for Carbon Composition Resistors

COLOR	NUMBER	COLOR	NUMBER	COLOR	TOLERANCE (%)
Black	0	Green	5	Gold	5
Brown	1	Blue	6	Silver	10
Red	2	Violet	7	COLOR	MULTIPLIER
Orange	3	Gray	8	Gold	0.1
Yellow	4	White	9	Silver	0.01

Title: Rocket Engine

Category: Innovation

Description:

A rocket moves because it is pushed by the reaction to the gases which escape from the nozzle of the rocket engine. The thrust developed by the rocket engine is determined by the mass of the gases flowing from the nozzle and their velocity. The greater the mass of gases escaping in a given period of time, the greater is the thrust developed. The faster the gases are moving, the greater is the thrust produced by the engine.

Science Concepts:

1. Newton's Third Law of Motion states for every force there is an equal and opposite force.
2. Combustion is a chemical reaction in which a fuel (black powder) combines with oxygen to produce energy.
3. Kinetic molecular theory states that all matter is made of molecules. Therefore, as temperature increases the movement of the molecule, the pressure inside a closed container also increases.
4. Pressure is a force applied per unit of area.
5. Force is any push or pull.
6. Thrust is a force causing a forward motion.

Title: Rocket Engine

Category: Innovation

Math Concepts:

1. Formulas

a. momentum = mv

momentum = mass x velocity

b. $P = \frac{F}{A}$

Pressure = $\frac{\text{Force}}{\text{Area}}$

c. $F = ma$

Force = mass x acceleration

d. $d = vt$

distance = velocity x time

2. Solving equations

3. Terminology

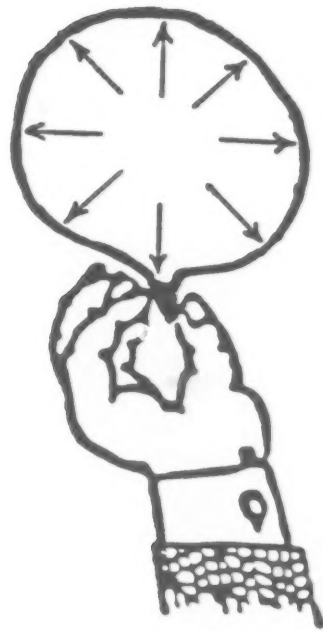
a. vertical

b. horizontal

c. degrees

4. Decimal and/or fraction computation

ROCKET ENGINE



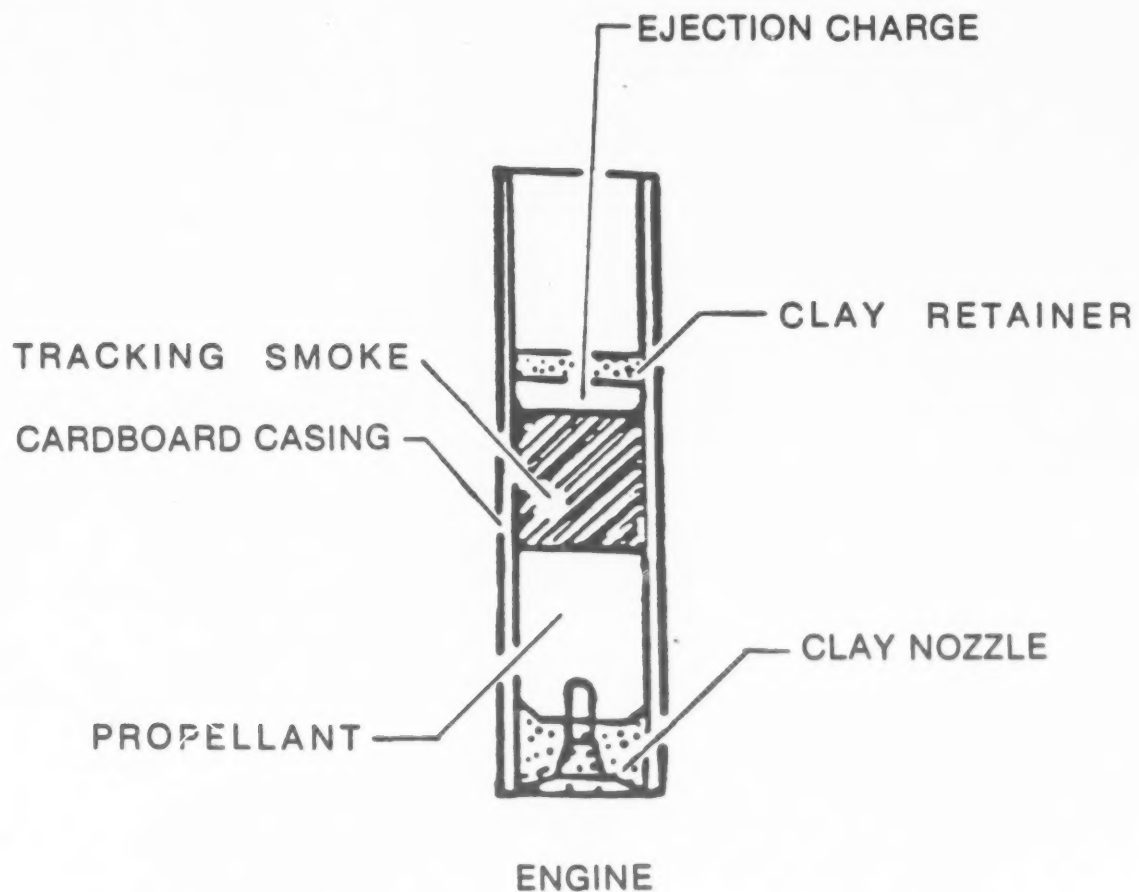
THE FORCE OF THE AIR PUSHING ON THE INSIDE SURFACE OF
THE BALLOON IS UNIFORM.

ROCKET ENGINE



THE ESCAPING AIR CREATES AN EQUAL FORCE IN THE OPPOSITE DIRECTION CAUSING THE BALLOON TO FLY FORWARD.

ROCKET ENGINE



ROCKET ENGINE

SCIENCE CONCEPTS

NEWTON'S

THIRD LAW OF MOTION

COMBUSTION

PRESSURE

THRUST

FORCE

MATH CONCEPTS

EQUATIONS

FORMULAS

$$P = \frac{F}{A}$$

$$F = ma$$

$$d = vt$$

TERMINOLOGY

HORIZONTAL

VERTICAL

DEGREES

Title: Rocketry

Category: R & E

Description:

A model rocket is mainly constructed from paper, plastic, balsa wood and glue. The diameter is about one inch and the length about twelve inches. A launch lug on the side of the rocket is attached to a three foot straight wire on the launch pad. This lug directs the rockets flight path at launch time. After launching, the fins at the base of the rocket guide the flight path. When the altitude is reached and the engine quits, a parachute is expelled to slow the return of the rocket to the ground.

Math Concepts:

1. $F = ma$

Force = mass x acceleration

2. $s = \frac{d}{t}$

speed = $\frac{\text{distance}}{\text{time}}$

3. $W = Fd$

Work = Force x distance

4. solving equations

5. ratio and proportion

6. measuring

7. geometric shapes

examples: hexagon

octagon

cone

cylinder

8. compute with fractions

9. line graph (altitude & time)

Title: Rocketry

Category: R & E

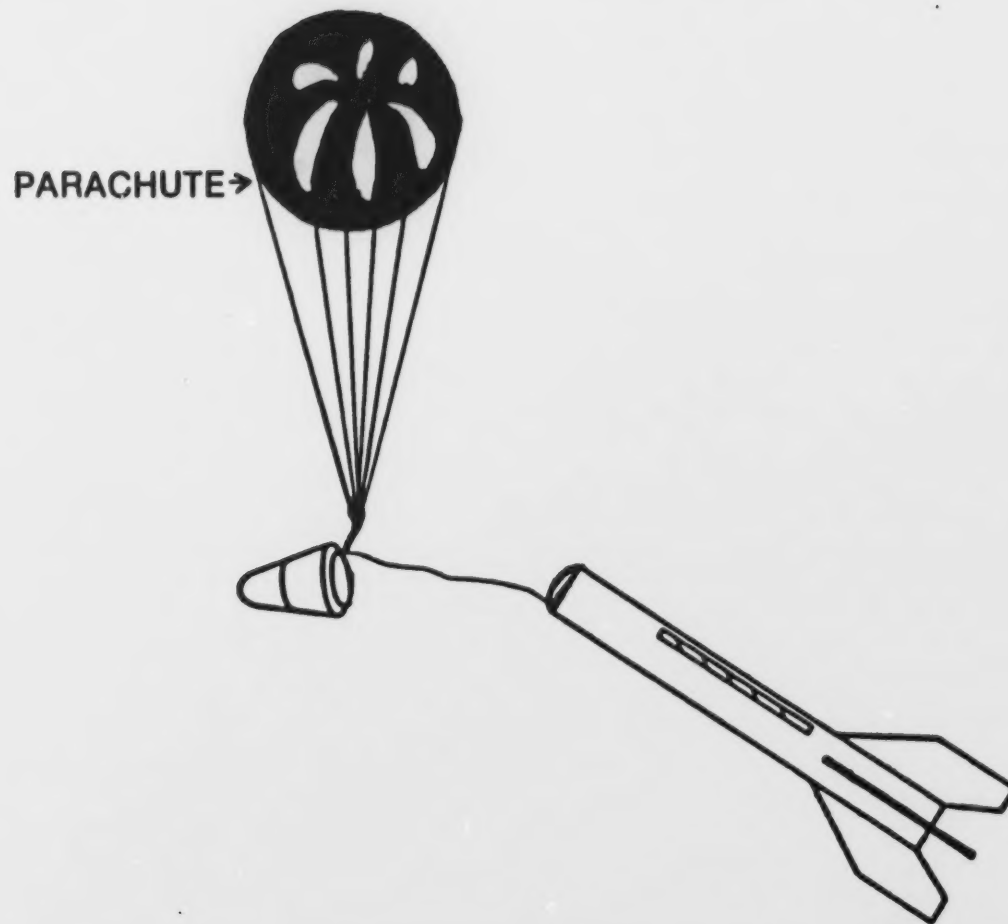
Science Concepts:

- 1) Energy is the ability to do work.
- 2) There are two types of energy; kinetic and potential.
- 3) Kinetic energy is the energy of motion.
- 4) Potential energy is stored energy.
- 5) Newton's first law of motion states that an object at rest tends to remain at rest or an object in motion remains in motion unless a force acts on it.
- 6) Newton's second law of motion states that acceleration of an object increases as the amount of force causing the acceleration increases.
- 7) Newton's third law of motion states that for every force there is an equal and opposite force.
- 8) Force is a push or a pull.
- 9) The four forces involved in flight are:
 - a) gravity - the force of attraction between all objects in the universe.
 - b) lift - a force used to overcome gravity.
 - c) drag - friction created when objects move in air.
 - d) thrust - the force needed to overcome drag.
- 10) Bernoulli's Principle: If a fluid is moving along a surface, the fluid will cause a force on that surface. This force will be perpendicular to the surface. If the fluid moves faster, it will cause less force on the surface.
- 11) Air resistance is the force of air against an object.
- 12) Friction is the force that opposes the motion.
- 13) Speed is the distance traveled per unit of time.

ROCKETRY

DRAG

GRAVITY



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AIR RESISTANCE IS THE FORCE OF AIR AGAINST AN OBJECT.

289

ROCKETRY

GEOMETRIC SHAPES

NEWTON'S LAWS OF MOTION

GRAPHING

EQUATIONS

ENERGY

$$F = ma$$

$$W = Fd$$

$$s = \frac{d}{t}$$

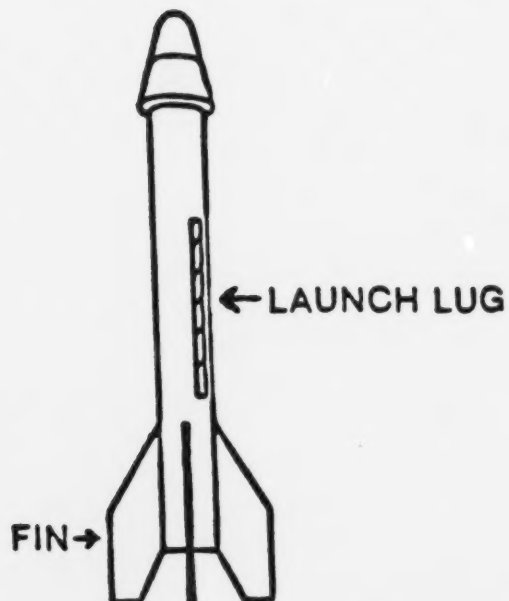
SPEED

DRAG

THRUST

GRAVITY

FRICTION



TITLE: SERIES CIRCUITRY

CATEGORY: SYSTEM

DESCRIPTION:

A series circuit has two or more loads connected in a single file, or in a series, across a common power supply. In such a circuit, there is only a single path for electrons, and if the circuit is broken at any point, no current will flow. Therefore both lights are either on or off.

Series circuits are less expensive to manufacture, since only one wire is used for each device. This reduces wiring and labor costs. In addition, several low-voltage units can be connected and used across a high-voltage source.

SCIENCE CONCEPTS:

1. In a light bulb, electrical energy is changed to heat energy and light energy.
2. Electric charges can be positive or negative.
3. 'Like' electric charges repel each other.
4. 'Opposite' electric charges attract each other.
5. Electrons have a negative charge.
6. An electric current in a metal is made of moving electrons.
7. An electric current always moves from a negative terminal to a positive terminal.
8. Electricity follows a path called an electric circuit.
9. A closed circuit is a complete path that electricity can move along.
10. An open circuit is an incomplete path that electricity cannot move along.
11. In a series circuit, there is just one path for the electrons to follow.
12. Electric current is measured in amperes.
13. The amount of current is the same in all parts of a series circuit.
14. Resistance is a measure of how easy or hard it is for electric current to move through a wire.
15. Conductors have low resistance and insulators have high resistance.
16. The resistance of a wire depends on its length, its thickness, the material it is made of and its temperature.
17. Resistance is measured in ohms.

SCIENCE CONCEPTS:

(CONTINUED)

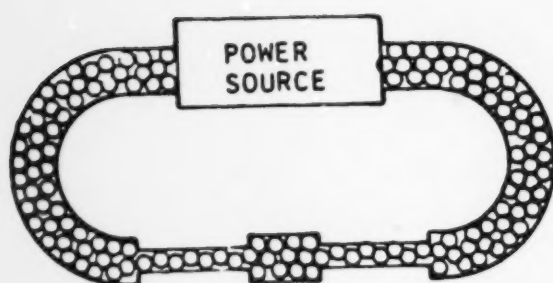
18. EMF holds atoms and molecules together. It is electric and magnetic forces together.
19. Ohm's Law states that the electric current in a circuit is equal to the EMF divided by the resistance.

MATHEMATICAL CONCEPTS:

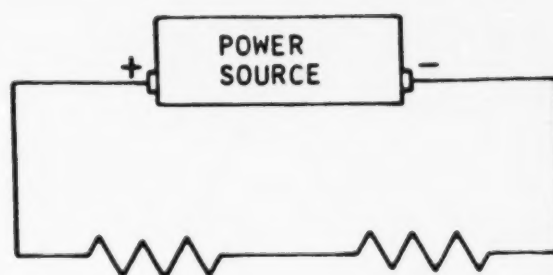
1. Ohm's Law $R = \frac{E}{I}$
R = resistance (ohms)
E = electric current (amperes)
I = electromotive force (volts)
2. $R_E = R_1 + R_2 + R_3$
R = Resistance in a series
R , R , R = Individual resistance
3. Multiplication of decimals
4. Division of decimals
5. Use of calculator
6. Order of operations

SERIES CIRCUITRY

SERIES CIRCUIT: A CIRCUIT THAT HAS JUST ONE PATH FOR THE ELECTRICITY TO FOLLOW



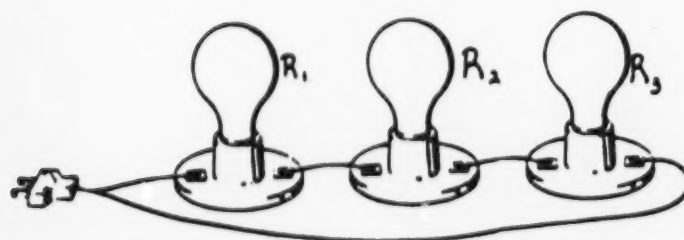
MARBLE FLOW IS LESS INTENSE WITH TWO NARROW PLACES THAN WITH ONE



IN SERIES CIRCUIT, EQUIVALENT RESISTANCE IS SUM OF INDIVIDUAL RESISTANCES

OHM'S LAW

$$R = \frac{E}{I}$$



$$R_E = R_1 + R_2 + R_3$$

Title: Series/Parallel Circuitry

Category: System

Description:

A series-parallel circuit has 2 or more components connected side by side and one or more components connected in single file. Voltage across the parallel branch are equal, but current is divided according to Ohm's and Kirchhoff's Laws.

Series parallel circuits are important where current and voltage division is necessary.

Mathematical Concepts:

1. Addition and subtraction of common fractions.
2. Addition and Subtraction of Decimals.
3. Multiplication and Division of Common Fractions
4. Multiplication and Division of Decimals.
5. Changing a fraction to a decimal and a decimal to a fraction.
6. Solve simple equations involving one-step.
7. Solve ratios and proportions.
8. Transfer a formula to express a particular variable in terms of other variables.
9. Solve fractional equations.
10. Define the term "Parallel"

MATHEMATICAL CONCEPTS:

11. Combination of OHM's Law and Power Law Equators.

EQUATION	OPERATION	RESULTANT
$E = \sqrt{P \times R}$	voltage = $\sqrt{\text{watts} \times \text{ohms}}$	volts (V)
$E = \frac{P}{I}$	voltage = $\frac{\text{watts}}{\text{amperes}}$	volts (V)
$E = I \times R$	voltage = amperes X ohms	volts (V)
$I = \frac{E}{R}$	current = $\frac{\text{volts}}{\text{ohms}}$	amperes (A)
$I = \frac{P}{E}$	current = $\frac{\text{watts}}{\text{volts}}$	amperes (A)
$I = \sqrt{\frac{P}{R}}$	current = $\sqrt{\frac{\text{watts}}{\text{ohms}}}$	amperes (A)
$P = I \times E$	power = amperes X volts	watts (W)
$P = I^2 \times R$	power = amperes ² X ohms	watts (W)
$P = \frac{E^2}{R}$	power = $\frac{\text{volts}^2}{\text{ohms}}$	watts (W)
$R = \frac{E}{I}$	resistance = $\frac{\text{volts}}{\text{amperes}}$	ohms (Ω)
$R = \frac{E^2}{P}$	resistance = $\frac{\text{volts}^2}{\text{watts}}$	ohms (Ω)
$R = \frac{P}{I^2}$	resistance = $\frac{\text{watts}}{\text{amperes}^2}$	ohms (Ω)

$$12. R_E = R_1 + \frac{R_2 \times R_3}{R_2 \times R_3}$$

BEST COPY AVAILABLE

Title: Series/Parallel Circuitry

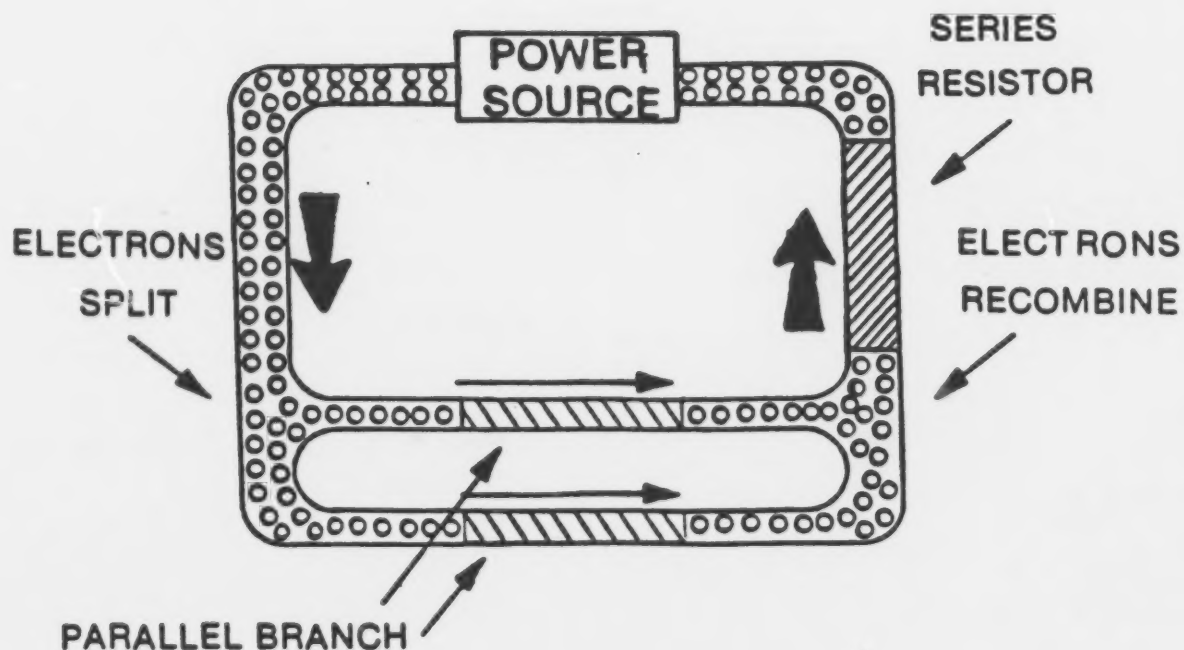
Category: System

Science Concepts:

1. Electricity is the flow of electrons and current.
2. The current is measured in units called amperes.
3. Voltage is electrical pressure that forces the current through the circuit and its value is measured in volts.
4. In electricity, like charges repel and unlike charges attract.
5. Opposition to the flow is the resistance.
6. The resistance is measured in units called ohms.
7. Electrons continuously flow through a wire in a closed circuit.
8. Electron current flows through a wire from minus - charge to plus + charge.
9. A complete circuit is required to permit electron flow.
10. In a series circuit, the same current flows through each resistor.
11. The voltage in a series circuit add together.
12. When resistors are connected in series, the resistance values are added.
13. To find the amount of current flowing in a series circuit, find the total resistance and use ohm's law.
$$\text{Current} = \frac{\text{Voltage}}{\text{Resistance}}$$
14. In a parallel circuit, the power sources may be connected in different paths to obtain a higher current capability.
15. In a series - parallel circuit, some components are connected in series and others connected in parallel.
16. "The sum of the currents entering a junction in a circuit equals the sum of the currents leaving that junction" (Kirchhoff's current law)
17. "The sum of the voltage drops (in any closed loop) is always equal to the applied voltage" (Kirchhoff's voltage law.)

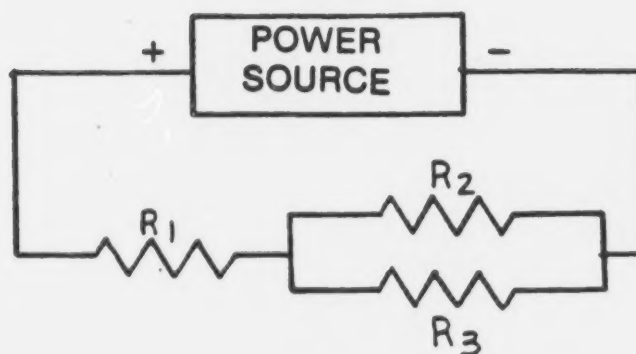
SERIES-PARALLEL CIRCUITRY

SERIES-PARALLEL CIRCUIT: A CIRCUIT IN WHICH ONE OR MORE GROUPS OF RESISTANCES IN PARALLEL ARE CONNECTED IN SERIES.



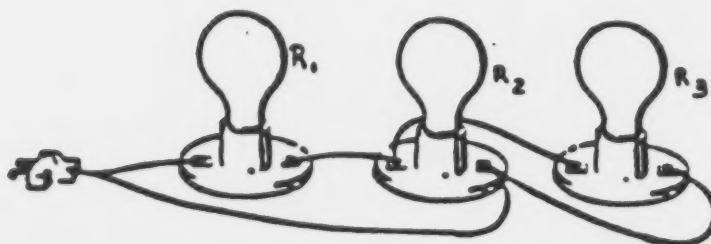
ELECTRON FLOW IS SPLIT AT THE PARALLEL BRANCH AND MUST RECOMBINE AT THE SERIES RESISTOR.

SERIES-PARALLEL CIRCUITRY



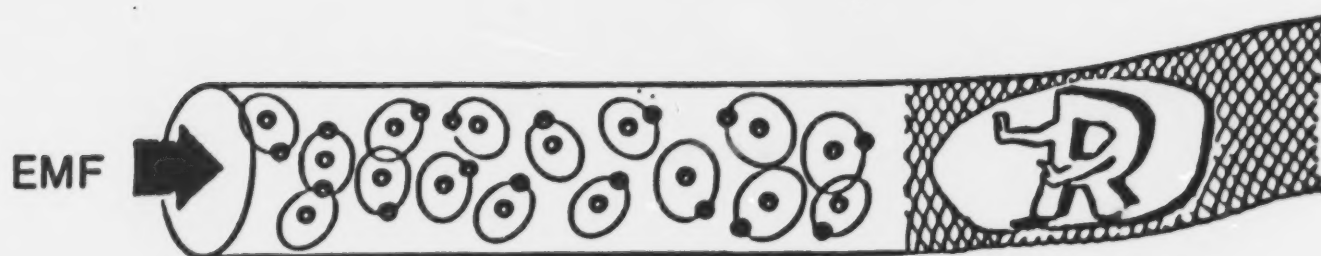
TOTAL RESISTANCE OF RESISTORS IN PARALLEL IS LESS THAN THE SMALLER RESISTOR AND MUST BE ADDED TO THE RESISTOR IN SERIES.

OHM'S LAW $R = E/I$



$$R_{EQUIV} = R_1 + \frac{R_2 \times R_3}{R_2 + R_3}$$

SERIES-PARALLEL CIRCUITRY



ELECTRO-MOTIVE FORCE

ELECTRO-MOTIVE FORCE IS A SOURCE OF ELECTRICAL ENERGY THAT CAUSES CURRENT FLOW IN A CIRCUIT BY TRANSFERRING VALENCE ELECTRONS.

RESISTANCE

RESISTANCE CAN BE SAID TO BE THE INTERNAL FRICTION INVOLVED IN THE PASSING OF ELECTRONS THROUGH A WIRE.

Title: Silicon Photovoltaic Cell

Description: The conversion of light energy (Photons) to electric energy (EMF) using the silicon photovoltaic cell is presented.

The construction and operation of the photovoltaic cell is presented using a simplified pictorial representation. Interconnection of the solar cells to produce desired voltages and currents is covered using an example of an array. The overall efficiency and inherent losses involved in a photovoltaic cell are presented through the use of a pie graph.

Science Concepts:

1. Examining the N - type and P - type silicon semiconductors used in the cell.

Pure silicon is a non-conductor because the valence electrons are localized in the four covalent bonds (4A atoms) that each atom forms with its neighbors in the crystalline lattice. To create a semi-conductor, small amounts of impurities are introduced into the silicon crystal. Arsenic (5A atoms) may be used to create the N - type semi-conductor and Boron (3A atoms) may be used to create the P - type semi-conductor. The arsenic provides the free electrons in one silicon wafer and the Boron provides the positive holes in the other silicon wafer. Doping the wafers with these impurities at a ratio of about 1:1,000,000 is sufficient to create a semi-conductor. The P-type and N-type wafers are then fused to together. At the P-N junction an area is created called the depletion region. Electrons and holes migrate across the P-N junction creating a barrier potential which prevents further net movement of electrons and holes. Electrons and holes, however, will continue to move across the P-N junction but in a state of equilibrium.

Light consists of small packets of energy called photons. When the photons strike valence electrons in the depletion region, energy is transferred to the electrons. The equilibrium is disturbed and the electrons and holes will be forced apart. The holes will move to the P-type crystal and the electrons will move to the N-type crystal producing a net flow of electrons from negative to positive. Electrons will pass through the load resistance, travel to the P-type crystal, move across the P-type crystal by hole movement, and return to the depletion region to once again absorb energy from photons.

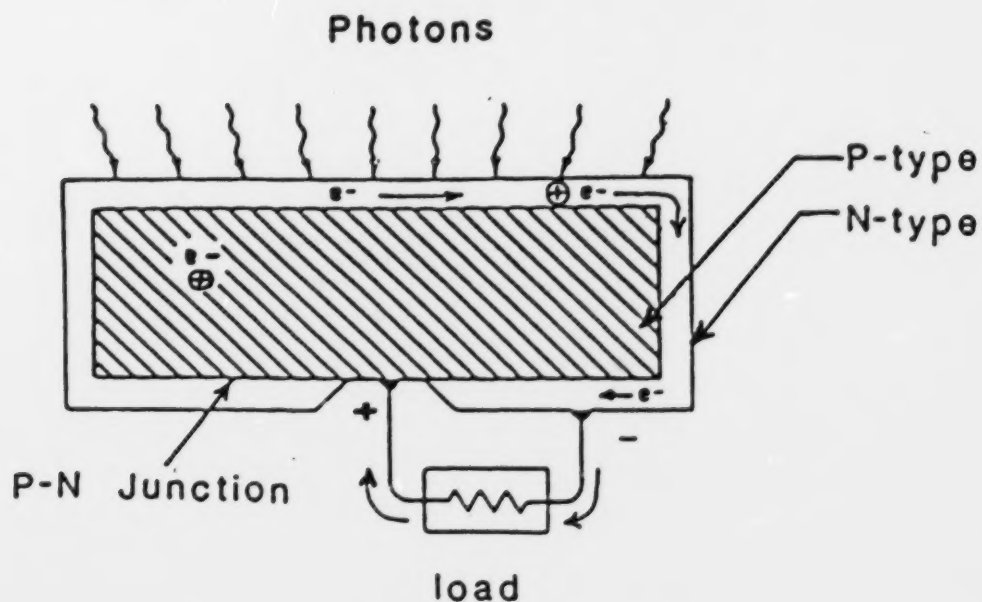
2. Recognizing the environmental effects of solar cells.

During normal solar cell operation there is virtually no negative environmental impact. Fossil - fueled and nuclear power plants pose far greater environmental hazards than do solar cells. Air contamination due to emissions associated with mining, transport, and processing ores used to produce solar cells as well as from environmental stress caused by the release of toxic substances if cells are burned accidentally must be addressed. Safe procedures for mining and manufacturing solar cells have been developed for the industry and must be enforced carefully to prevent environmental damage. A study of toxic substances released during a fire indicates little need for concern because such small quantities of these substances are used in the solar cell. Yet another area for concern is the effect of local changes of temperature and airflow caused by increased absorption of solar energy when solar cells are used in many large arrays. No serious effects on global atmospheric behavior have been identified when computer models have been used to simulate widespread use of large scale solar arrays.

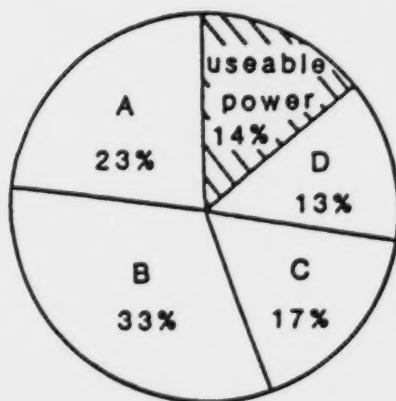
Math Concepts:

1. Reading a pie graph.
2. Multiplying and dividing decimal numbers.
3. Recognizing decimal-percent equivalents.
4. Converting percent to decimal.
5. Reading and interpreting graphs and/or tables analyzing cost, efficiency, density, resistivity and energy of the photovoltaic cell.
6. Finding the total voltage output, current output and power output of a cell array. As an example, on the transparency we have 5 modules per branch and if each module has an electric potential of .6 volts, we multiply $5 \times .6$ to get a potential of 3 volts. Also, if each branch has a current of 10.0 milliamps (mA) and the transparency shows 4 branches, then the current flow is 10×4 or 40 mA. The power output is the product of the voltage output (3v in our example) and the current output (40 mA) In this example, the power output is 120 mw.
7. Determining what percent of one number that another number is. The pie graph on the transparency was made from the schematic diagram below.

SILICON PHOTOVOLTAIC CELL

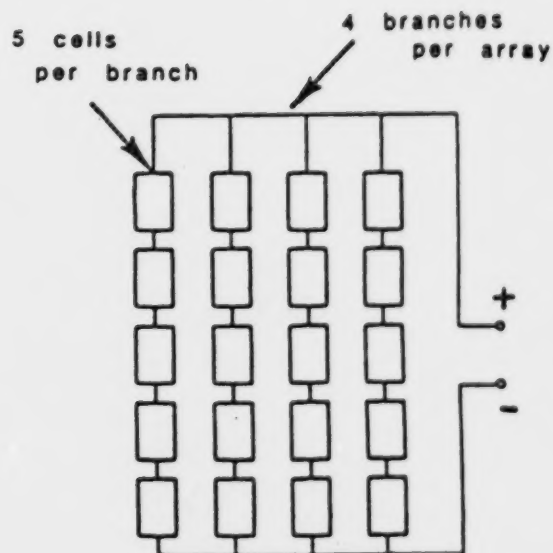


LIGHT INCIDENT PHOTONS



- A Photons not absorbed
- B Converted to heat
- C Junction loss
- D Losses to recombination, curve factor, resistance, reflection.

ARRAY



Title: Simple Machines

Description: These transparencies illustrate the six fundamental simple machines. These machines are a) lever; b) pulley; c) screw; d) inclined plane; e) wedge; f) wheel and axle. Included are force diagrams, definitions, and formulas for each machine.

Science Concepts:

General Concept: WORK IN = WORK OUT

$$F_1 d_1 = F_2 d_2 \quad (\text{assuming 100\% efficiency})$$

A. Lever:

$$\begin{aligned} &(\text{effort force}) \times (\text{its distance from fulcrum}) = \\ &(\text{resistance force}) \times (\text{its distance from fulcrum}) \end{aligned}$$

B. Pulley:

$$\begin{aligned} &(\text{effort force}) \times (\text{distance force moves}) = \\ &(\text{resistance}) \times (\text{distance resistance moves}) \end{aligned}$$

C. Screw: a spiral inclined plane.

D. Inclined Plane:

$$\begin{aligned} &(\text{effort force}) \times (\text{distance along plane}) = \\ &(\text{resistance force}) \times (\text{vertical distance}) \end{aligned}$$

E. Wedge: A double inclined plane with twice the mechanical advantage of a simple inclined plane.

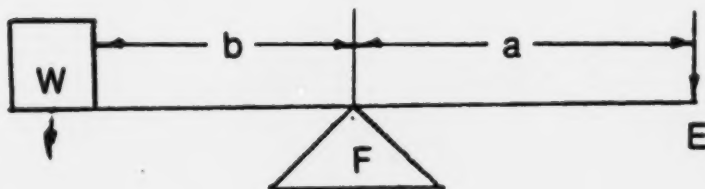
F. Wheel and Axle: Consists of a) a larger radius disc (radius = R) capable of having a force applied to the perimeter and b) a smaller radius rod (radius = r) capable of transmitting a force along its circular perimeter.

SIMPLE MACHINES

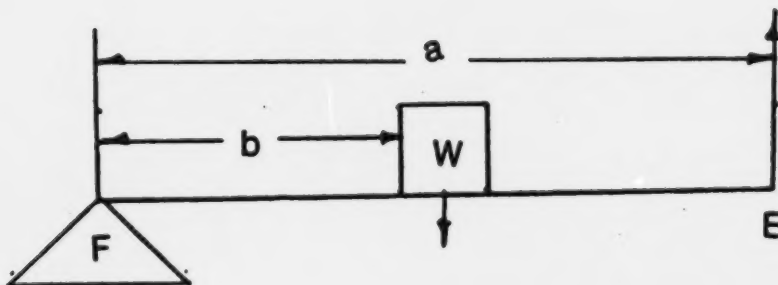
Six Fundamental Simple Machines

- a) lever b) pulley c) screw d) inclined plane
e) wedge f) wheel & axle

LEVERS: an inflexible rod capable of motion about a fixed point called a fulcrum



F = FULCRUM OF THE LEVER



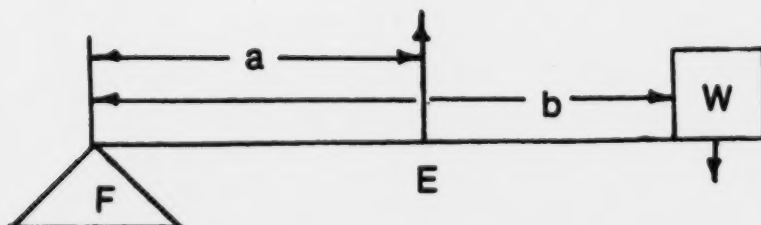
$$E \cdot a = W \cdot b$$

E = force

a = force distance from fulcrum

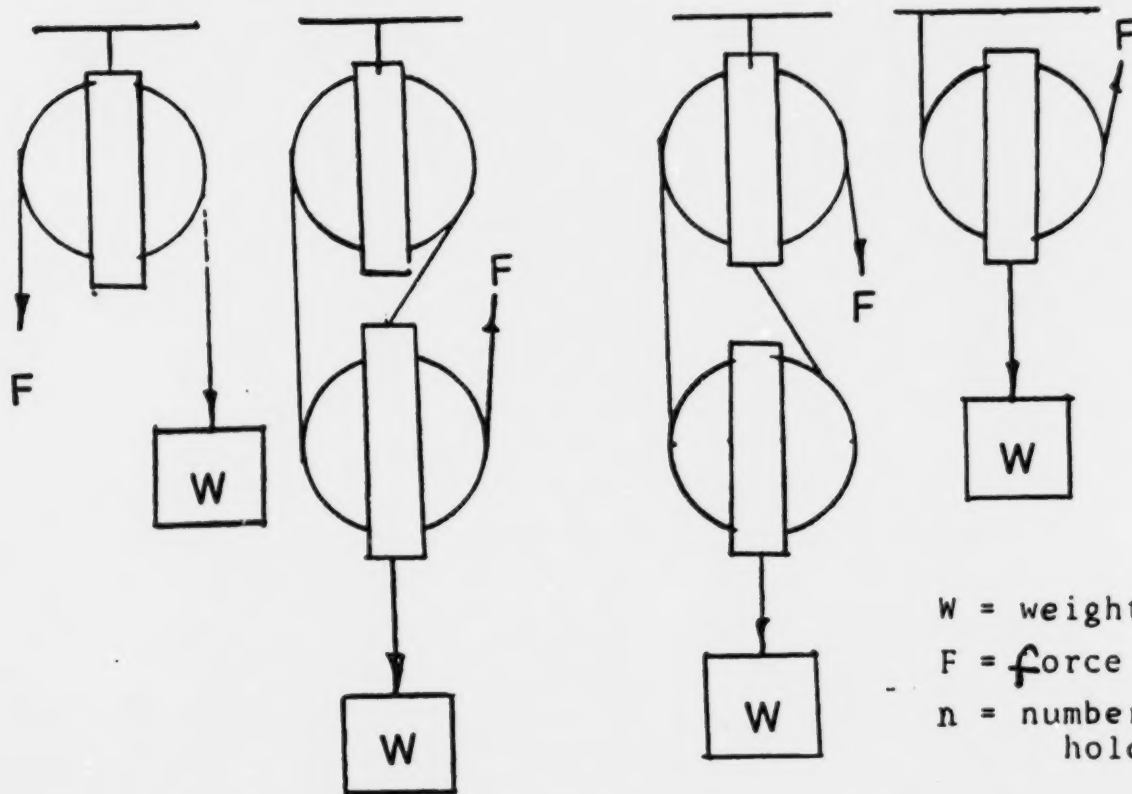
W = weight

b = weight distance from fulcrum



SIMPLE MACHINES

PULLEYS: A simple machine which multiplies the effort force by the ratio: Ropes holding up weight



$$W = F \cdot n$$

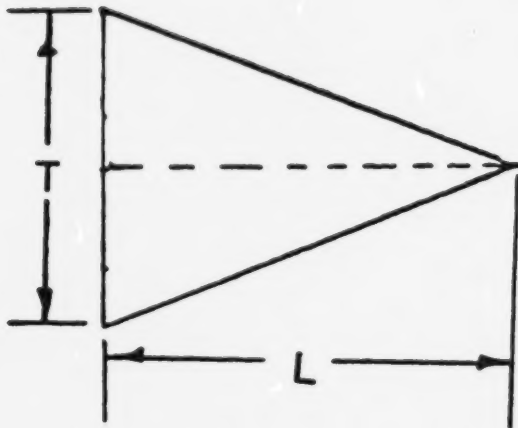
W = weight

F = force

n = number of moving strands holding the weight

SIMPLE MACHINES

WEDGES : A pair of inclined planes united at their bases.



$$\frac{F}{W} = \frac{T}{L}$$

F = force

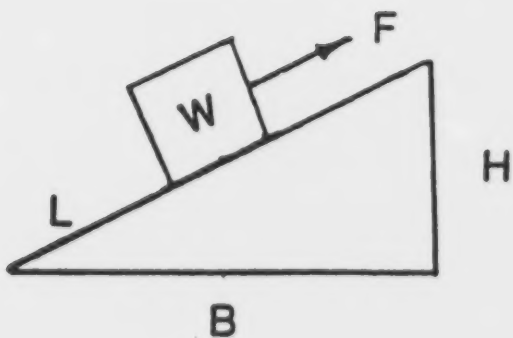
w = weight

T = thickness of wedge at base

L = length of wedge

SIMPLE MACHINES

INCLINED PLANES : A plane inclined or sloping from the horizontal.



$$F = \frac{W H}{L}$$

F = force

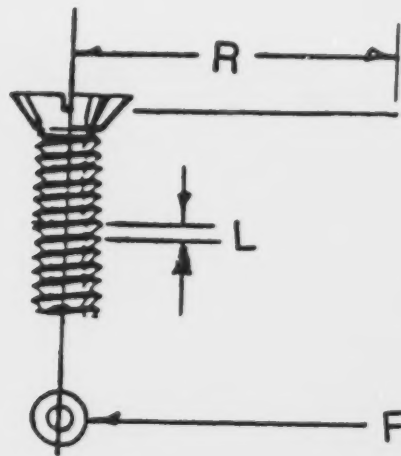
H = height to which weight
is to be raised.

L = length of inclined plane

W = weight

SIMPLE MACHINES

SCREWS : A spiral inclined plane.



$$\frac{F}{W} = \frac{L}{2\pi R}$$

R = length of bar

F = force

W = weight

L = lead of screw

TITLE: SMOCK WINDMILL

CATEGORY: INNOVATION

DESCRIPTION:

A WINDMILL IS COMPOSED OF METAL OR CLOTH FAN BLADES 12-16 FEET IN DIAMETER MOUNTED ON A HORIZONTAL SHAFT AND HAVING A TAIL VANE TO KEEP THE ROTOR FACING INTO THE WIND. THE BLADES CAPTURE THE WIND AND BEGIN TO TURN, CAUSING THE SHAFT TO ALSO TURN. THE SHAFT IS CONNECTED TO A SET OF GEARS AND A CAM THAT MOVES A CONNECTING ROD UP AND DOWN. THIS MOTION IN TURN OPERATES THE PUMP OR THE MILL LOCATED AT THE BOTTOM OF THE TOWER. WINDMILLS WERE FIRST USED FOR MILLING GRAINS OR LIFTING WATER. TODAY WINDMILLS ARE USED NOT ONLY FOR THE PUMPING OF WATER, BUT ALSO FOR GENERATING ELECTRICITY.

TITLE: SMOCK WINDMILL

CATEGORY: INNOVATION

SCIENCE CONCEPTS:

1. BERNOULLI'S PRINCIPLE: IF A FLUID IS MOVING ALONG A SURFACE, THE FLUID WILL CAUSE A FORCE ON THAT SURFACE. THIS FORCE WILL BE PERPENDICULAR TO THE SURFACE. IF THE FLUID MOVES FASTER, IT WILL CAUSE LESS FORCE ON THE SURFACE.
2. LIFT- UPWARD FORCE OF AIR MOVING AROUND AN OBJECT.
3. INCREASE LIFT BY:
 - A. INCREASING THE SURFACE OF THE BLADE
 - B. INCREASING THE ANGLE OF ATTACK
4. DRAG- FRICTION CREATED WHEN OBJECTS MOVE IN AIR,
5. FRICTION- A FORCE THAT ACTS TO SLOW DOWN A MOVING OBJECT THAT IS PASSING THROUGH OR AGAINST A MATERIAL. A FORCE IS A PUSH OR A PULL.
6. SIMPLE MACHINE- A DEVICE THAT HELPS YOU DO WORK BY INCREASING FORCE, INCREASING SPEED, OR CHANGING THE DIRECTION OF THE FORCE.

WHEEL AND AXLE- A SIMPLE MACHINE THAT IS A TYPE OF LEVER.

LEVER AND FULCRUM- A BAR OR BOARD THAT IS FREE TO PIVOT ABOUT A FIXED POINT CALLED THE FULCRUM.

GEARS- A KIND OF WHEEL-LIKE MACHINE THAT ACTS LIKE A LEVER.
7. WORK IS THE RESULT OF A FORCE ACTING ON A BODY AND MOVING IT THROUGH A DISTANCE.
8. ENERGY IS NEEDED FOR WORK TO BE DONE.
9. ENERGY CONVERSION OCCURS AS ENERGY IS BEING TRANSFERRED FROM KINETIC TO MECHANICAL ENERGY.

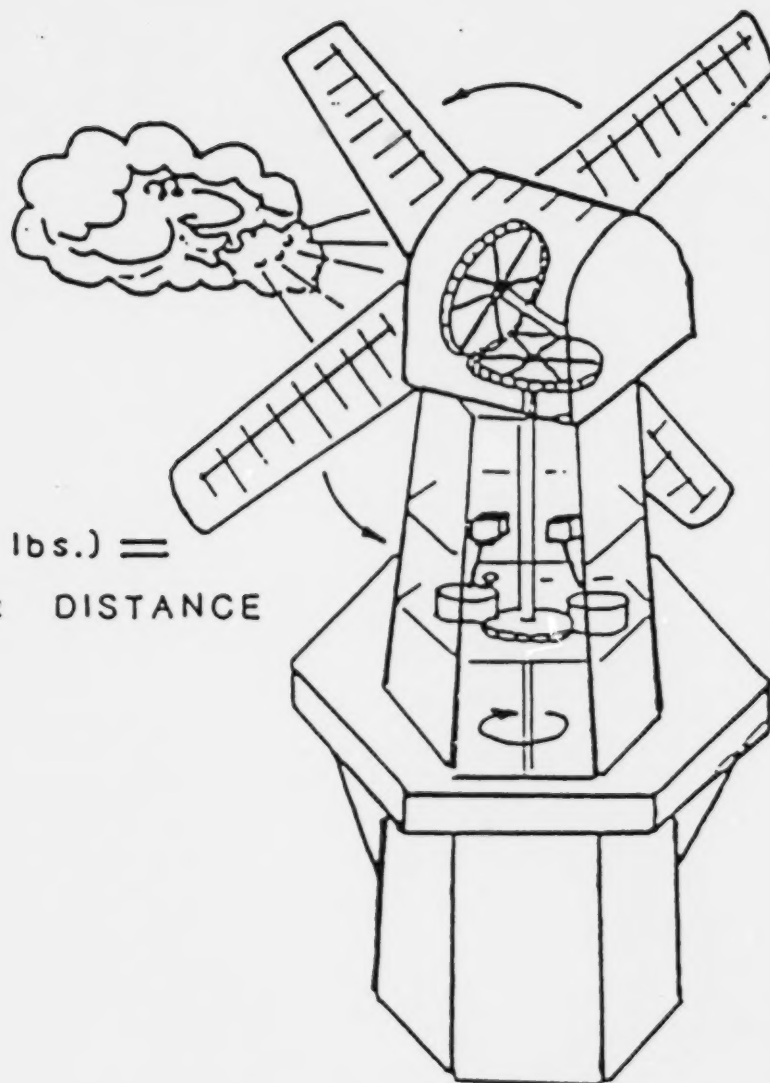
SCIENCE CONCEPTS:

10. WIND IS PRODUCED BY THE SUN HEATING THE AIR ABOVE THE EARTH UNEVENLY; AS THE WARM AIR RISES, COOLER AIR RUSHES IN TO REPLACE IT.
11. WIND IS A RENEWABLE SOURCE OF ENERGY.

MATH CONCEPTS:

1. $L = v\Delta t$ DISTANCE = VELOCITY $\times$ TIME
 Δt = TIME WHICH KINETIC ENERGY IS TRANSMITTED TO THE BLADES
2. $V = AL$ VOLUME OF AIR = AREA OF BLADES $\times$ DISTANCE
VOLUME OF AIR = $A = \pi r^2 \times$ DISTANCE
SUBSTITUTING: $V = Av\Delta t$
3. $M = dV$ MASS = DENSITY $\times$ VOLUME
SUBSTITUTING: $M = dAv\Delta t$
4. $P = \frac{1}{2}dAv^3$ POWER = $\frac{1}{2} \times$ DENSITY $\times$ AREA $\times$ VELOCITY³
5. MULTIPLICATION OF DECIMALS
6. MULTIPLICATION OF FRACTIONS
7. EXPONENTS
8. TORQUE (NEWTON-METER) = LENGTH OF LEVER ARM $\times$ FORCE

SMOCK WINDMILL

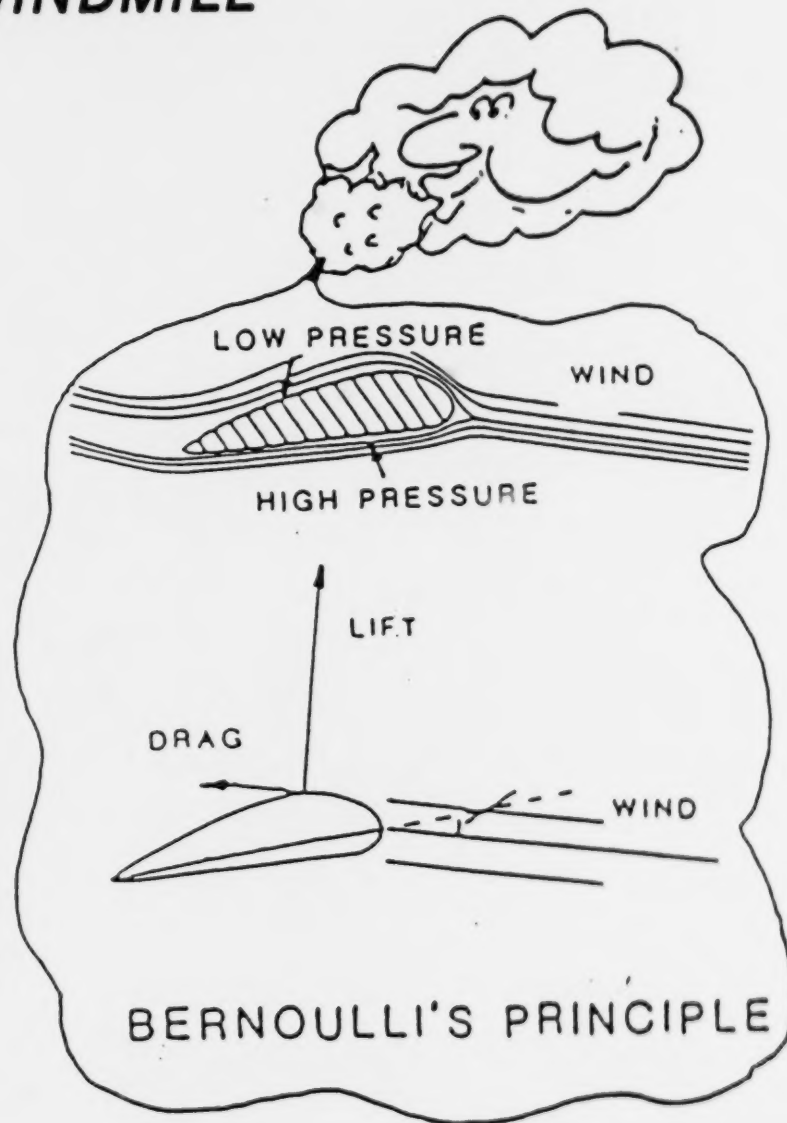
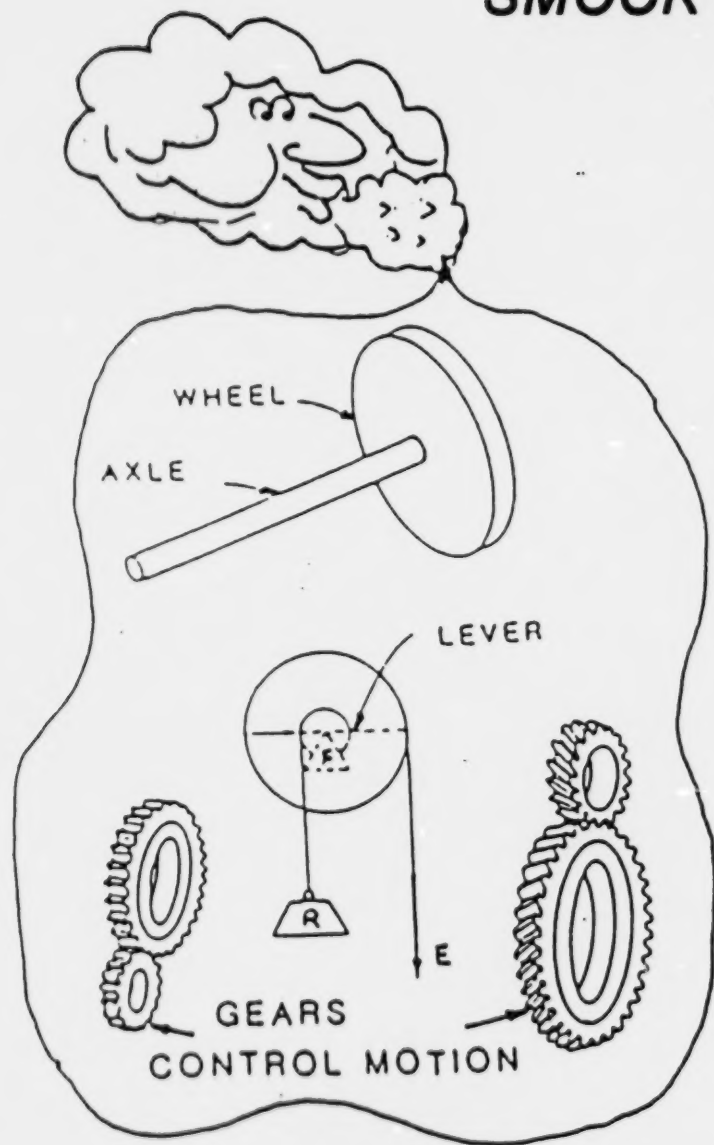


WORK(ft. lbs.) =
FORCE x DISTANCE

$$MA = \frac{\text{OUTPUT FORCE}}{\text{INPUT FORCE}}$$

$$MA = \frac{L(E)}{L(R)}$$

SMOCK WINDMILL



TITLE: SOLAR HEATING

CATEGORY: SYSTEMS

DESCRIPTION:

Solar heating refers to the capture, storage, and subsequent re-radiation of the sun's energy to provide relatively inexpensive heating of homes and other buildings.

SCIENCE CONCEPTS:

1. Thermonuclear Reaction--
 - a. sun consists primarily of hydrogen.
 - b. core temperature is approximately 25,000,000 F.
 - c. due to high temperature and pressure, hydrogen nuclei fuse (nuclear fusion) to produce helium and energy.
 - d. every second the sun converts 4 million tons of hydrogen into radiant energy.
2. Elliptical orbit--the earth's orbit is not perfectly circular but, rather, elliptical, with the sun slightly off-center, at one focus.
3. Perihelion--point in earth's orbit at which it is closest to sun.
January 1.
4. Aphelion--point in earth's orbit at which it is furthest from sun.
July 1.
5. Plane of the ecliptic--plane which passes through the center of the sun and the earth's orbit.
6. Declination--angle between equatorial plane and plane of ecliptic.
7. Summer solstice--June 21 or 22; declination is +23.5 .
8. Winter solstice--December 21 or 22; declination is -23.5 .
9. Spring and fall equinoxes--March 20 or 21 and September 20 or 21 respectively. Declination is 0 .
10. Altitude--angle of sun above horizon.
11. Azimuth--angle of sun east or west of due south.
12. Radiant energy is converted to heat energy when it is absorbed.
13. Insolation--total amount of solar radiation received by a given area of the earth's surface at any given time.
14. Heat--the sum total of all molecular energy of a body.
15. Temperature--a measure of the intensity or quantity of heat stored in a body.

SCIENCE CONCEPTS:

(CONTINUED)

16. Specific heat--the quantity of heat, in Btu's, needed to raise the temperature of one pound of material 1°F.
17. Conduction--the transfer of heat energy through a material by the motion of adjacent atoms and molecules.
18. Convection--the transfer of heat energy through moving currents of fluids as a result of thermal gradients and resulting density differences.
19. Radiation--the transfer of heat energy through space which does not require a transfer medium.

MATHEMATICAL CONCEPTS:

1. An ellipse is a set of points. The sum of the two distances from a point on an ellipse to the foci is constant.
2. Foci is the plural of focus. An ellipse has two fixed points of focus known as the foci.
3. The graph of an ellipse may be sketched using the equation $\frac{x^2}{A^2} + \frac{y^2}{B^2} = 1$ and substituting values for A and B.
4. The major axis in an ellipse is the longer axis of symmetry. The minor axis in an ellipse is the shorter axis of symmetry.
5. Two measures of temperature are fahrenheit and celsius.
6. Degrees fahrenheit may be converted to degrees celsius using the formula:
Celsius = $\frac{5}{9}$ (fahrenheit - 32)
7. Degrees celsius may be converted to degrees fahrenheit using the formula:
Fahrenheit = $\frac{9}{5}$ celsius + 32
8. Solar Saving Percentage is the percentage of energy saved by a passive solar building compared to a "conventional building."
9. Solar Saving Percentage
$$\text{S.S.P.} = 1 - \frac{\text{Furnace Heat Required By Solar Building}}{\text{Furnace Heat Required By Comparable Nonsolar Building}} \times 100$$
10. The amount of surface area glass used in a building affects the solar heating efficiency.
Surface Area = Length x Width (Rectangular Glass)

SOLAR ENERGY

SCIENCE CONCEPTS

THERMONUCLEAR REACTION

EARTH'S ORBIT

SEASONS

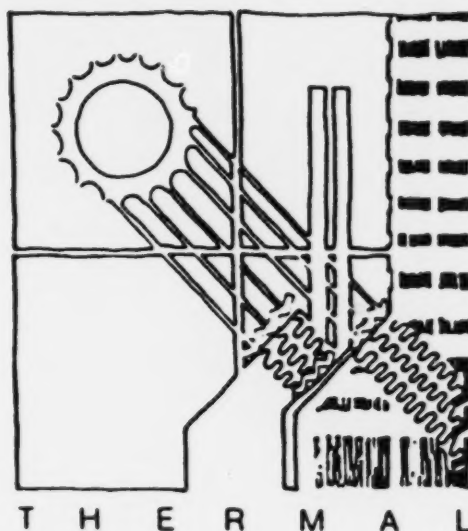
PATH OF SUN

ENERGY CONVERSION

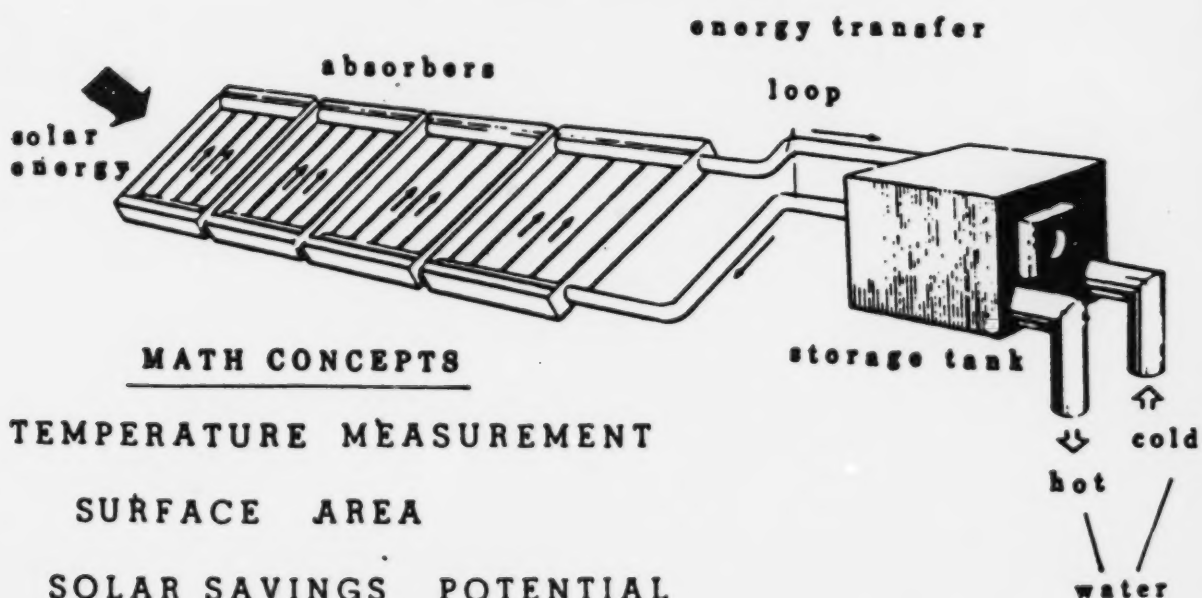
INSOLATION

TEMP. vs HEAT

HEAT TRANSFER



SOLAR WATER HEATER



MATH CONCEPTS

TEMPERATURE MEASUREMENT

SURFACE AREA

SOLAR SAVINGS POTENTIAL

ELLIPTICAL SHAPE

TITLE: SOLAR HEATING

CATEGORY: SYSTEMS

DESCRIPTION:

The use of solar energy, by using the sun as a source of heat, can halt our growing dependence on energy sources that are polluting the environment. The solar energy reaching the earth every three days is greater than the estimated total of all the fossil fuels on earth. Solar heating in domestic hot water systems can provide a large percentage of a dwelling's hot water requirements.

SCIENCE CONCEPTS:

1. The First Law of Thermodynamics states that energy is neither created nor destroyed. Energy is changed from one form to another.
2. Sunlight is a form of radiant energy and it is essential to life on earth.
3. Sunlight contains radiant energy in both the visible and non-visible spectrum.
4. Radiant energy can be described in terms of wavelengths. Wavelengths are measured in units called microns.
5. A micron is 1/1000th of a millimeter.
6. Sunlight contains infrared and ultraviolet wavelengths of radiant energy that are not visible.
7. Dark colors absorb most wavelengths of the visible spectrum while light colors tend to reflect most of these wavelengths.
8. Light travels in straight lines.
9. Light travels at a speed of 186,000 miles per second.
10. Light can be reflected, refracted, transmitted, and absorbed.
11. Glass will transmit solar radiation. Glass, however, absorbs long wave thermal radiation, thus creating the "Greenhouse Effect."
12. Water will store tremendous quantities of energy.
13. Intensity of thermal energy is measured in degrees Fahrenheit or Celsius.
14. A quantity of heat is measured in British Thermal Units (BTU's) or in calories. A BTU is the amount of thermal energy needed to raise one pound of water, one degree Fahrenheit. A calorie is the amount of thermal energy needed to raise one gram of water, one degree Centigrade.
15. Energy can be transferred by conduction, convection, and radiation.

SCIENCE CONCEPTS:

(CONTINUED)

16. The earth orbits the sun once every $365 \frac{1}{4}$ days. During its orbit, the earth's inclination toward the sun varies.
17. The earth's inclination toward the sun, not its proximity to the sun, determines the intensity of the sun's radiation.
18. Solar collectors are inclined at an angle that equals the latitude of its site on the earth. This inclination is adjusted by $\pm 23 \frac{1}{2}$ for summer and winter.
19. Solar collectors should face south for efficiency.

TITLE: SOLAR HEATING

CATEGORY: SYSTEM

MATHEMATICAL CONCEPTS:

1. Temperature measures.
2. Temperature conversions.

$$F = \frac{9}{5} C + 32$$

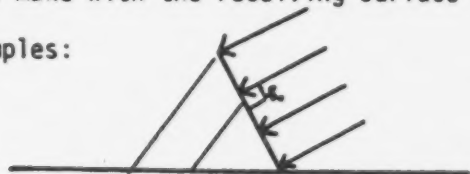
F = Degrees Fahrenheit

C = Degrees Centigrade

Fractional multiplication and order of operations are involved.

3. Angle measures for axis of tilt and angle of incidence.
4. Concepts of horizontal, vertical, and perpendicular lines for angles of incidence.
5. Trigonometric values, specifically sine and cosine.
The intensity of the solar radiation received is adjusted by multiplication by (1) the cosine of the angle the striking rays make with a line perpendicular to the receiving surface or (2) the sine of the angle the striking rays make with the receiving surface itself.

Examples:



$$\cos 0^\circ = 1$$

$$\sin 90^\circ = 1$$

so the intensity is full strength.



$$\cos 60^\circ = \frac{1}{2}$$

$$\sin 30^\circ = \frac{1}{2}$$

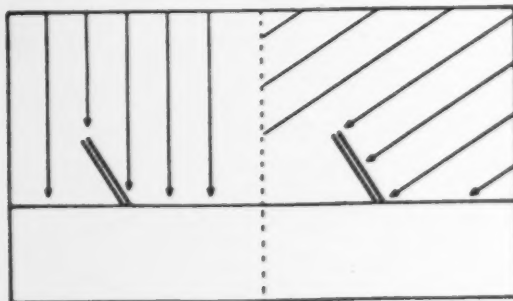
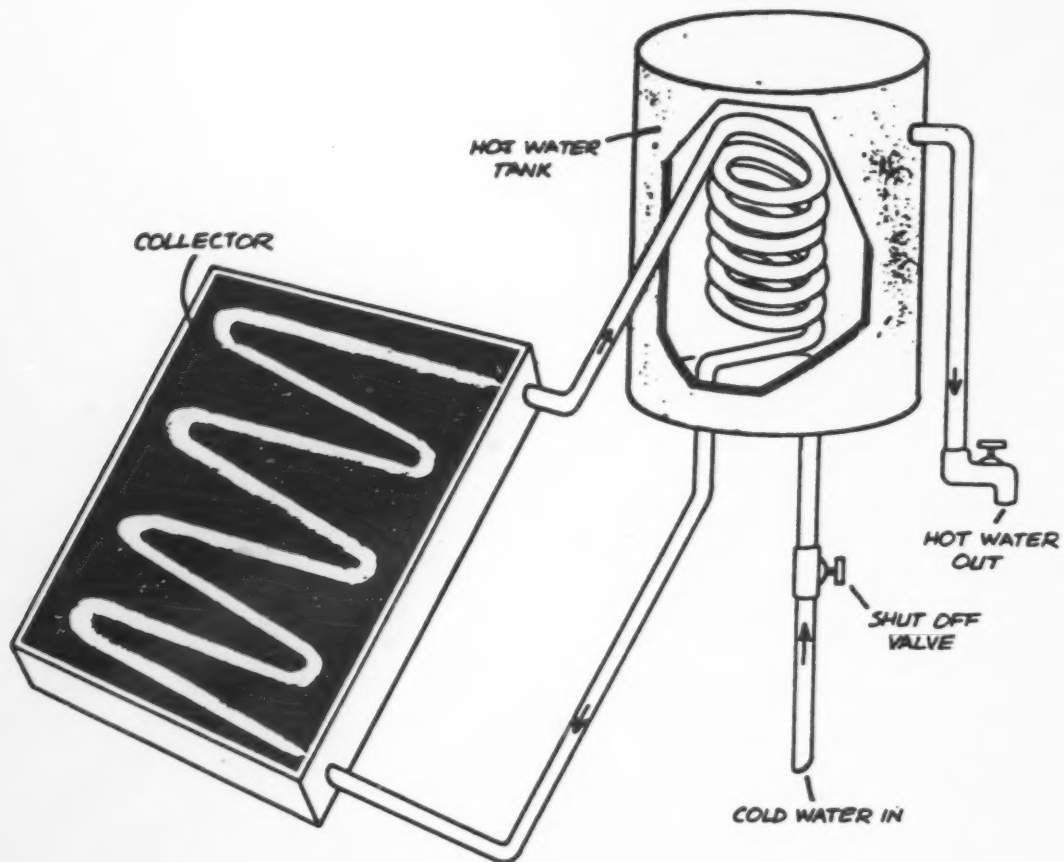
so the intensity is halved.

6. Concepts behind parabolic reflectors and lenses for focusing and concentration of solar power.
7. Concept and measure of wavelength. Division and multiplication by 1000 (movement of the decimal point) in converting between microns and millimeters.

$$1000 \text{ microns} = 1 \text{ millimeter}$$

$$1 \text{ micron} = \frac{1}{1000} \text{ millimeter}$$

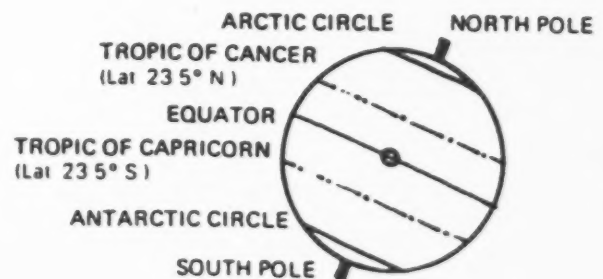
SOLAR HEATING



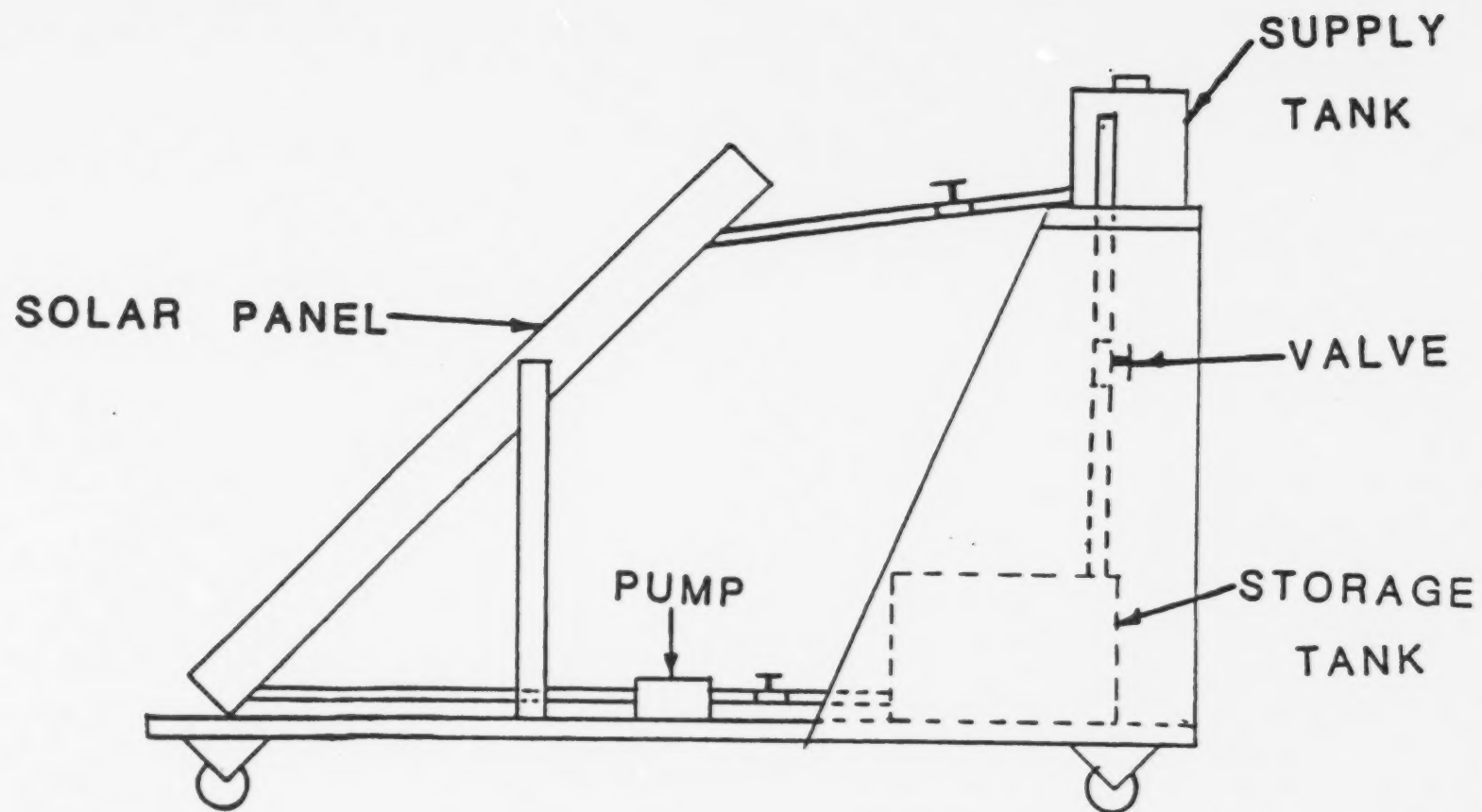
COSINE LAW — TILTED SURFACE

THE SAME LAW APPLIES TO A TILTED SURFACE SUCH AS A SOLAR COLLECTOR. BY TILTING THE COLLECTOR SO THAT IT IS MORE NEARLY PERPENDICULAR TO THE SUN, MORE ENERGY STRIKES ITS SURFACE.

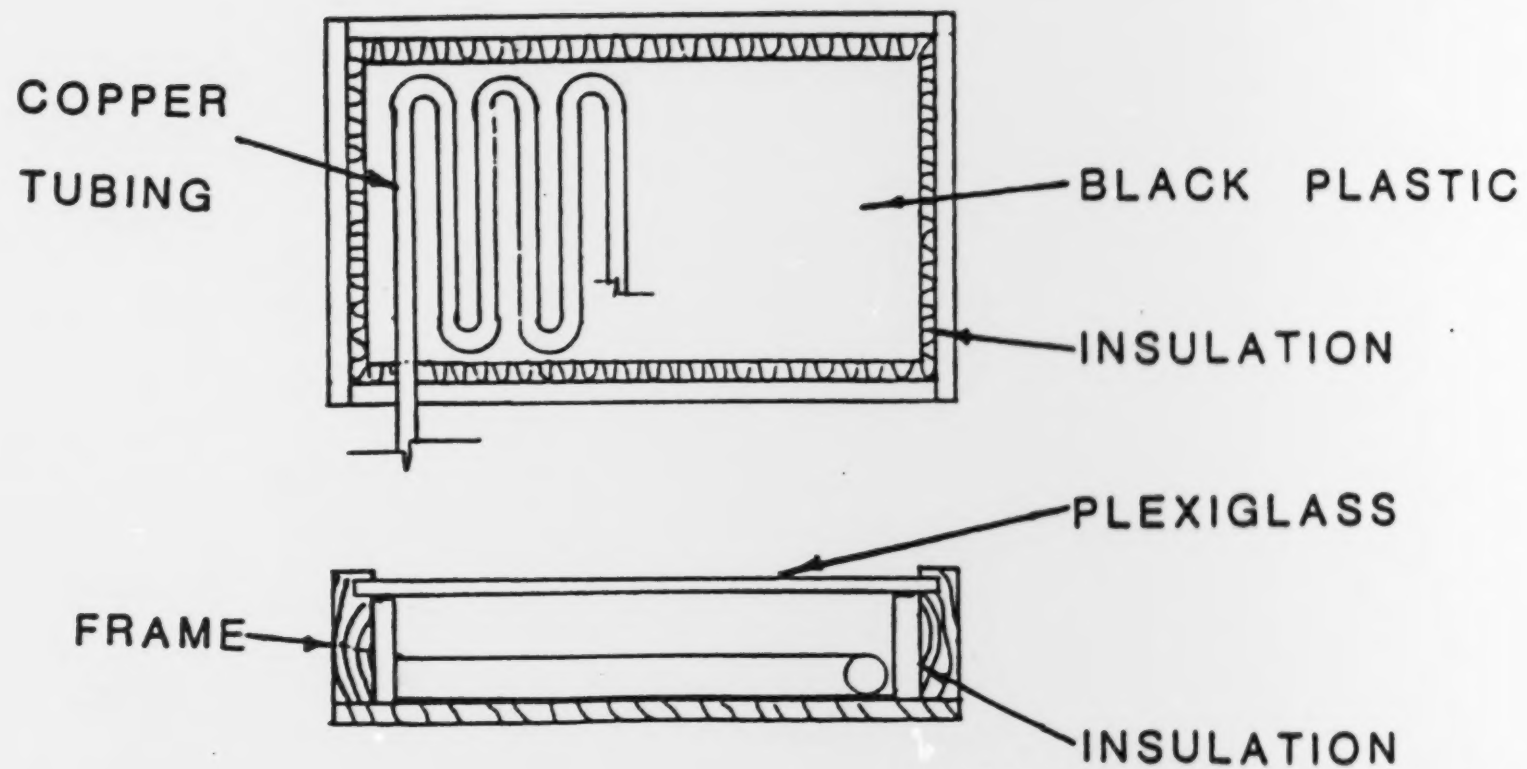
WHAT THE SUN 'SEES'



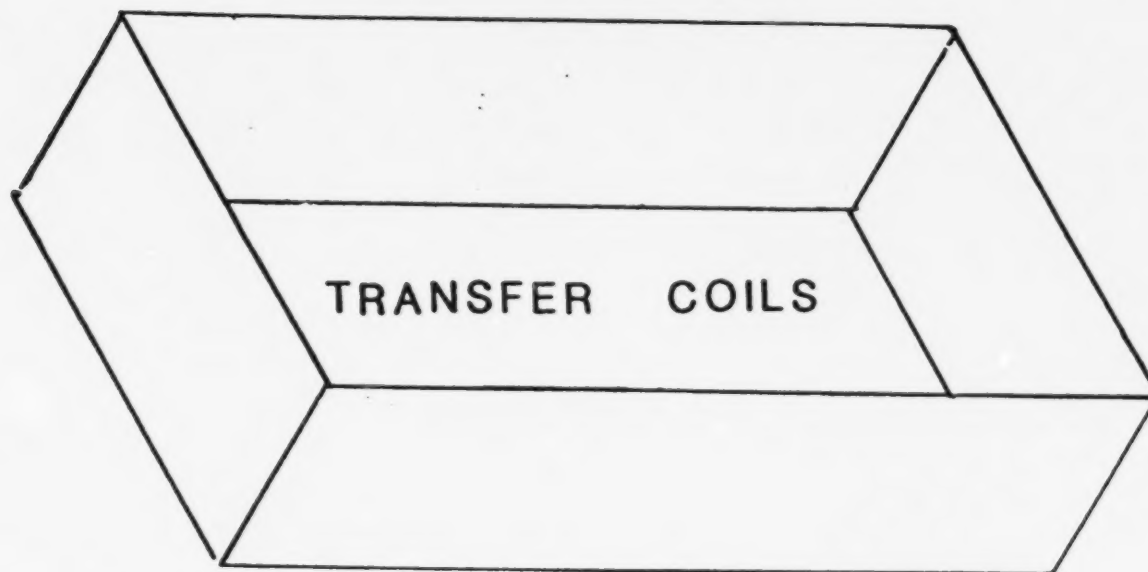
SOLAR HEATER



SOLAR HEATER



TEMPERATURE RISE IN A STORAGE TANK



$$\Delta T = (T_2 - T_1) = \frac{Q}{C_p M}$$

C_p = Heat capacity in calories per degree per gram

M = mass in grams

T_2 = High Temperature

T_1 = Low Temperature

Q = Total Heat (calories)

Title: Solar Water Heater

Category: Systems

Description:

The drain-back solar water heater is an auxillary system to aid an existing hot water tank. The solar collector of the unit is composed of a wooden frame containing 6" of fiberglass insulation, "S" shaped copper tubing and an etched glass glaze.

The collector is attached to the incoming (cold) water pipe of the hot water tank in such a way that the system can be easily operated during times when the sun is shining, and turned off when it is cool or cloudy. The system can also be easily drained when freezing temperatures are expected.

The drain-back system is cheap to construct, easy to install, and should significantly reduce the energy consumption of an existing hot water tank.

Math Concepts:

1. $V = \pi r^2 h$

Volume (of cylinder) = π x radius² x height

2. $\Delta Q = mc \cdot \Delta T$

Heat transfer = mass of liquid x specific heat x change in temperature.

3. $\Delta l = \alpha l_0 (\Delta T)$

Change in length = linear expansion constant x initial length x change in temperature.

4. $HC = \frac{\Delta Q}{\Delta T}$

Heat capacity = heat transfer $\div$ change in temperature.

5. Multiplication of fractions

6. Multiplication of decimals

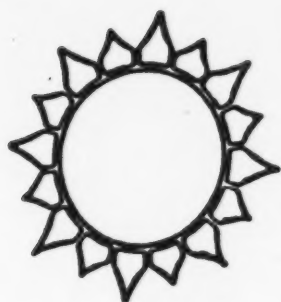
7. Exponents

Title: Solar Water Heater

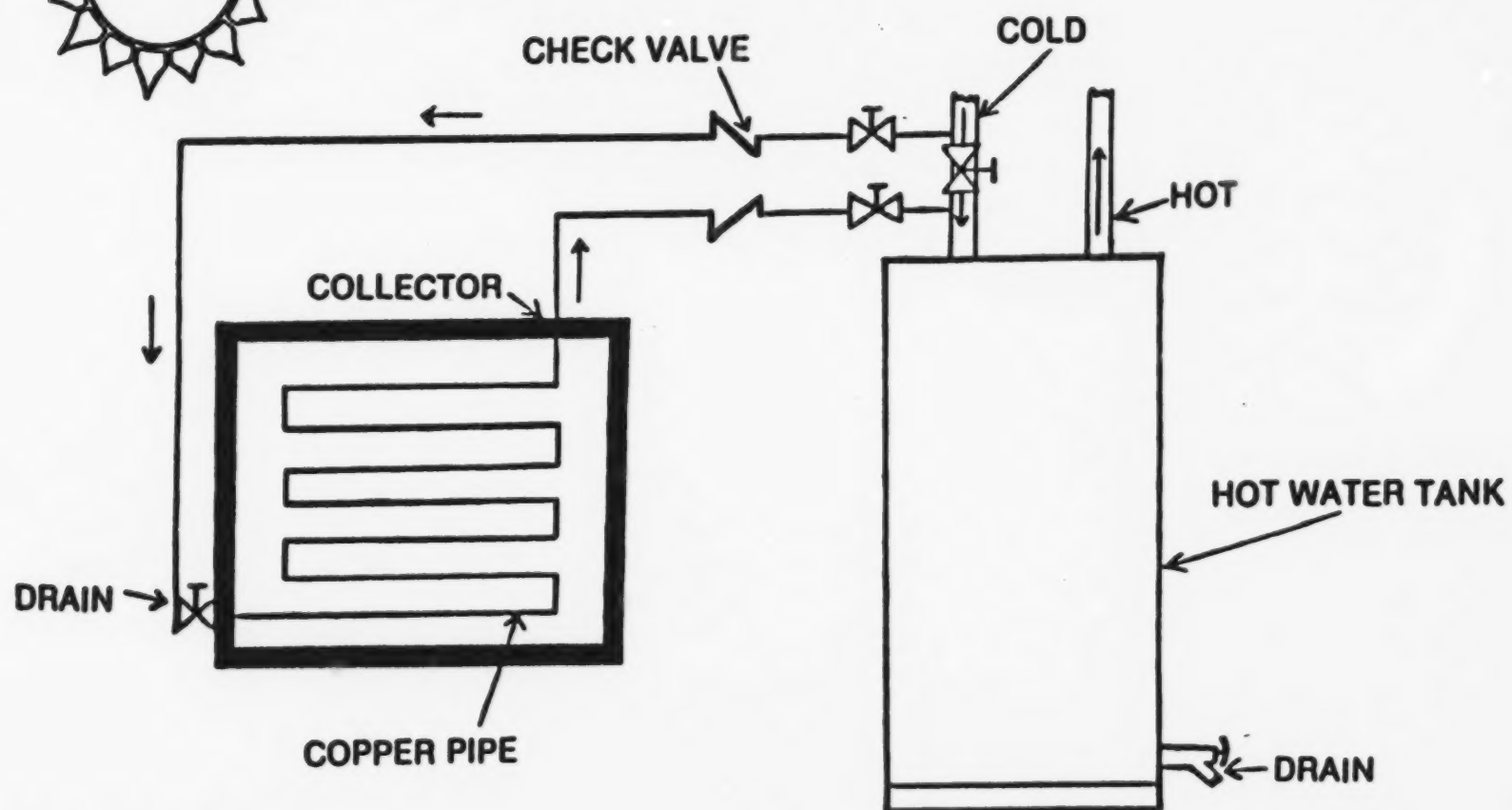
Category: Systems

Science Concepts:

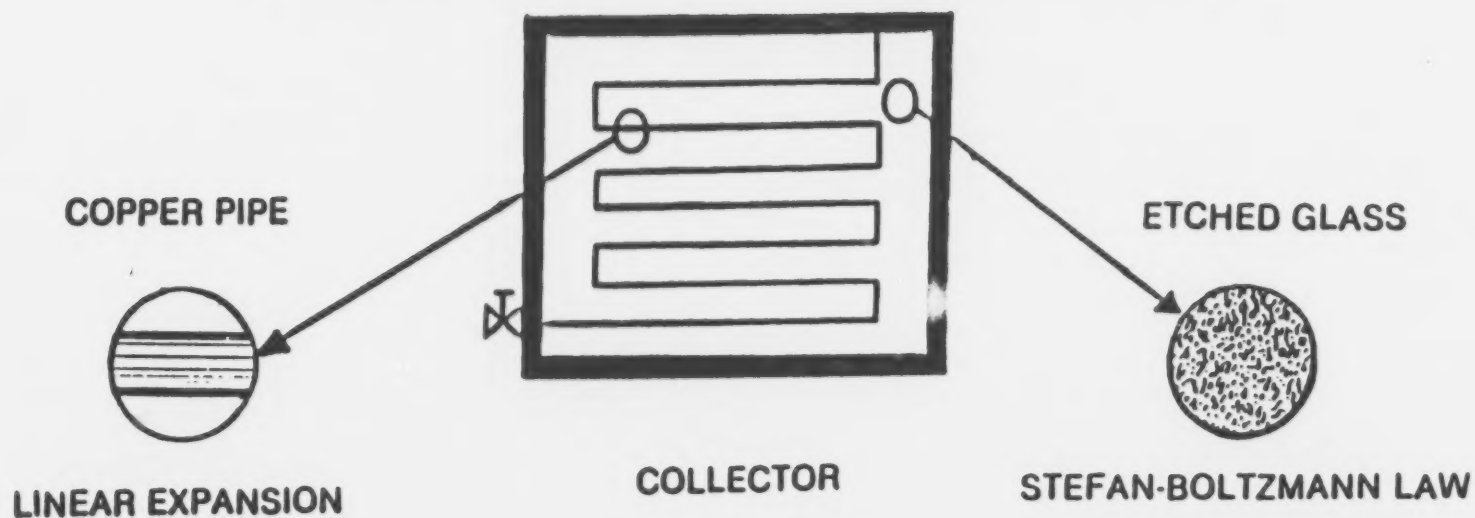
1. Greenhouse Effect - Phenomenon in which radiant energy passes through a transparent material at a direct angle, is converted to heat when it bounces off an object at an indirect angle, and then is reflected back by the inside of the transparent material.
EXAMPLE: Interior of car in summer.
2. Heat Transfer -
 - A. Radiation - the transfer of energy through electromagnetic waves usually converted to heat when absorbed by matter.
 - B. Conduction - method of heat transfer caused by molecular collisions
 - C. Convection - heat transfer in fluids in which the warmer, less dense materials move up, and the colder, more dense materials move down.
3. Specific Heat - is that quantity of heat needed to raise the temperature of a given substance one degree celsius
4. Insulator - a material that is a poor conductor.
5. Reflection - the property of some surfaces to return rays of light that strike them.
6. Etching - process in which a shiny surface is dulled by chemical or mechanical means to lower reflectivity.
7. Temperature - thermal condition of a material depending on average kinetic energy of the molecules.
8. Linear Expansion - the tendency of a solid material to expand or contract with a change in temperature.



SOLAR WATER HEATER



SOLAR WATER HEATER



$$\Delta l = \alpha l_0 (\Delta T)$$

Δl = CHANGE IN LENGTH

α = COEFFICIENT OF LINEAR EXPANSION
(.000017 FOR COPPER)

l_0 = INITIAL LENGTH

ΔT = CHANGE IN TEMPERATURE

$$I = \epsilon \sigma T^4$$

I = ENERGY RADIATED

ϵ = EMISSIVITY

σ = RADIATION CONSTANT

T = ABSOLUTE TEMPERATURE

TITLE: TRANSFORMERS

CATEGORY: INNOVATION

DESCRIPTION:

A transformer consists of a primary and one or more secondary windings, wound on a common core. By choosing the proper number of turns on the primary and secondary windings, a step-up transformer provides a higher secondary than primary voltage. A step-down provides a smaller secondary than primary voltage. The voltage times current product of the primary must equal that of the secondary.

SCIENCE CONCEPTS:

1. A transformer is a device which transfers energy from one circuit to another by electromagnetic induction.
2. Induction is the property in an electric circuit which resists a change in current.
3. A magnet has two poles, one north pole and one south pole.
4. A magnetic field is a group of imaginary lines along which a magnetic force acts. These lines emanate from the north pole and enter the south pole, forming closed loops.
5. A step-up transformer will increase the voltage and reduce the current (amperage). This type of transformer is used for sending high voltage over long distance.
6. A step-down transformer will decrease voltage and increase current (amperage). This type of transformer is commonly used to alter electricity entering homes.
7. A transformer is constructed of two or more coils of wire that are wound around a laminated iron core.
8. The first coil or winding, on a transformer, is the input, and it is called the Primary.
9. The second coil or winding, on a transformer, is the output load, and it is called the Secondary.
10. The energy in the secondary winding of a transformer is caused by the movement of the electromagnetic field of the primary winding across the secondary winding, and inducing a voltage in the secondary.
11. The output voltage of a transformer is directly proportional to the ratio of primary windings to secondary windings.
12. The output amperage of a transformer is inversely proportional to the ratio of primary windings to secondary windings.

TITLE: TRANSFORMERS

CATEGORY: INNOVATION

MATHEMATICAL CONCEPTS:

1. Computation of total inductance in series without magnetic coupling

$$L_T = L_1 + L_2 + \dots + L_n$$

2. Computation of total inductance of 2 series inductors with magnetic coupling

$$L_T = L_1 + L_2 \pm 2m \text{ (m is the mutual inductance)}$$

Use "+2m" when magnemotive forces of the inductors are aiding each other.

Use "-2m" when magnemotive forces of the inductors are opposing each other.

3. Computation of total inductance in parallel

$$\frac{1}{L_T} = \frac{1}{L_1} + \frac{1}{L_2} + \dots + \frac{1}{L_n} \text{ or } L_T = \frac{1}{\frac{1}{L_1} + \frac{1}{L_2} + \dots + \frac{1}{L_n}}$$

4. Formulas for computation in step-up and/or step-down transformers

E_p = Primary voltage

I_p = Primary current

N_p = Number of turns in primary inductor

N_s = Number of turns in secondary inductor

E_s = Secondary voltage

I_s = Secondary current

- a) The ratio of the turns is the same as the ratio of the voltage

$$\frac{E_p}{E_s} = \frac{N_p}{N_s}$$

algebraic manipulations to compute:

$$N_p = N_s \times \frac{E_p}{E_s}$$

$$N_s = N_p \times \frac{E_s}{E_p}$$

$$E_p = \frac{N_p}{N_s} \times E_s$$

$$E_s = \frac{N_s}{N_p} \times E_p$$

- b) The ratio of the turns is the inverse of the ratio of the current

$$\frac{I_p}{I_s} = \frac{N_s}{N_p}$$

algebraic manipulations to compute:

$$I_p = \frac{N_s}{N_p} \times I_s$$

$$I_s = \frac{N_p}{N_s} \times I_p$$

$$N_p = \frac{I_s}{I_p} \times N_s$$

$$N_s = \frac{I_p}{I_s} \times N_p$$

MATHEMATICAL CONCEPTS:

(CONTINUED)

5. Concept of power as a constant in transformers.
6. Concept that in a transformer as voltage increases from primary to secondary circuit, the current drops and vice versa.

Since $P = I \times E$, an increase in I causes a decrease in E since P is constant. For the same reason an increase in E causes a decrease in I .

$$I = \frac{P}{E} \text{ or } E = \frac{P}{I} \text{ (P is constant)}$$

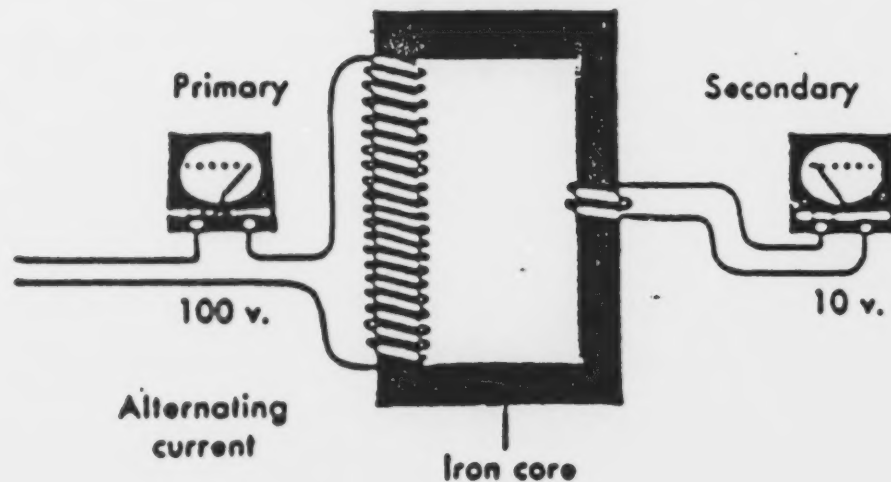
For example: If $P = 1200$ watts

If primary voltage is 1200 volts, then the current is 1 amp.

If the secondary voltage becomes 120 volts, then the current becomes 10 amps.

TRANSFORMERS

STEP-DOWN TRANSFORMER



Conductor

Current

Electricity

Iron Core

Magnetism

Primary

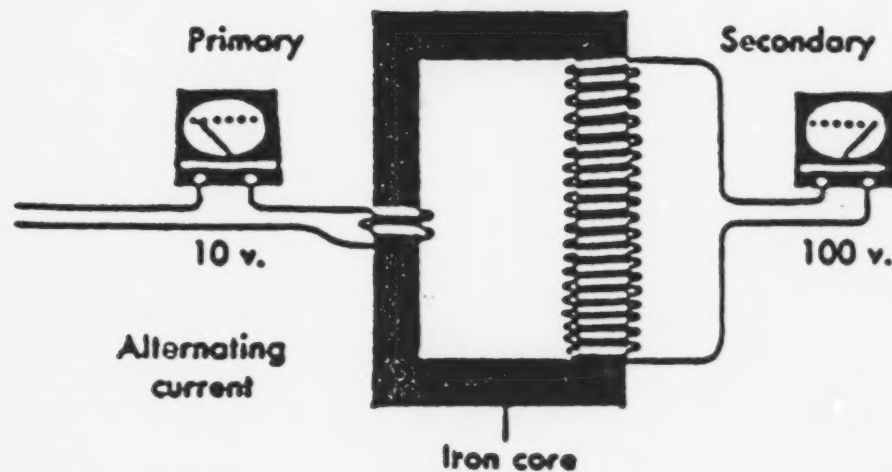
Secondary

$$\text{EFFICIENCY \%} = \frac{\text{OUTPUT}}{\text{INPUT}} \times 100$$

$$\text{ENERGY} = \text{VOLTAGE} \times \text{CURRENT}$$

TRANSFORMERS

STEP-UP TRANSFORMER



99% EFFICIENT

Efficiency Ratio

$$\text{EFFICIENCY \%} = \frac{\text{OUTPUT}}{\text{INPUT}} \times 100$$

$$\text{ENERGY} = \text{VOLTAGE} \times \text{CURRENT}$$

Title: The Transformer

Description:

A simple transformer can be made in industrial arts classes. This important device can demonstrate the value of changing voltage and how important it is to our everyday lives. The principles of electromagnetic induction are easily understood while processes, construction and operation of this device will offer immediate appreciation of this part of an electrical system.

Science Concepts

1. Transformer - a device that changes the voltage of an alternating current of electricity. Transformers have 3 main parts.

a. Primary winding - a coil that receives the full amount of generated energy.

b. Secondary winding - a coil that provides the output voltage.

c. Laminated iron core - a rectangular iron core around which the primary and secondary coils are wound.

2. Electromagnetism - the induction of electricity through magnetism.

When two separate pieces of wire are wound around an iron ring current generated in one wire will induce current in the second wire, even though the wires do not touch. As the electricity is generated through the first wire it creates magnetic lines of force. As they grow with the growing current, they cut the second wire, and generate current there. When the current is cut off, the lines of force collapse, and they cut the second wire again, generating current again.

3. Step-up Transformer - If the turns of the second coil of wire were ten times as many as the number of turns on the first coil, the voltage of the second current would be ten times greater than the first current. The voltage would be stepped-up.

4. Step-down Transformer - If the number of turns on the second coil were less than the number of turns on the first, the voltage of the current would be proportionally less than the voltage of the first current. Thus the voltage would be stepped-down.

Title: The Transformer
Description:

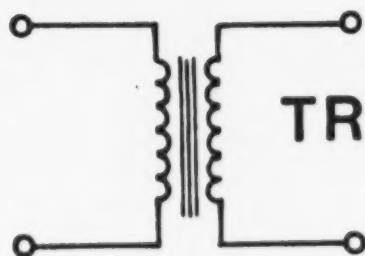
A simple transformer can be made in industrial arts classes. This important device can demonstrate the value of changing voltage and how important it is to our everyday lives. The principles of electromagnetic induction are easily understood while processes and construction of the transformer are taking place. The construction and operation of this device will offer immediate appreciation of this part of an electrical system.

Math Concepts:

1. A transformer is a device that changes voltage. The voltage put into a transformer is either stepped up or stepped down.
2. A door chime circuit uses a transformer to change 120 volts to 16 volts.
3. The transformer is over 99% efficient because it has no moving parts. This efficiency can be measured by the ratio of the output power at the secondary terminals to the input power at the primary terminals. That is:

$$\text{Efficiency} = \frac{\text{Output}}{\text{Input}}$$

4. The necessity for transformers stems from the heat generated from the resistance of the flow of electrons which causes a loss in electrical energy. Since the energy is equal to voltage x current, the greater the value of voltage, the smaller is the current required to produce the same amount of energy.
5. The amount of voltage induced in the secondary winding depends upon the ratio of the primary and secondary windings. i.e. if the electrical energy received at the primary winding is 13,200 volts and five times that at the secondary winding, then the output is $13,200 \times 5 = 66,000$ volts. The output is determined by the ratio of the number of turns in the primary coil compared to the number of turns in the secondary coil:



TRANSFORMERS

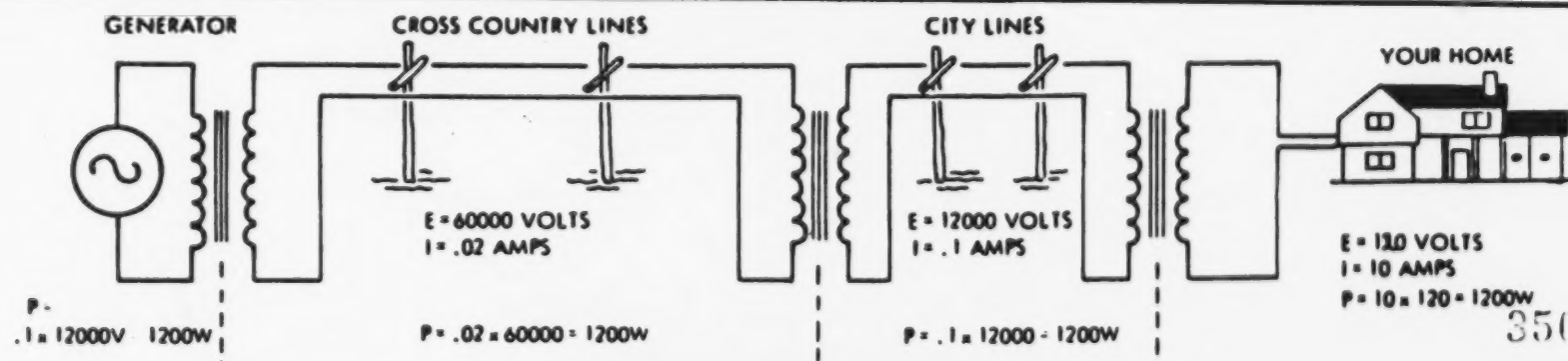
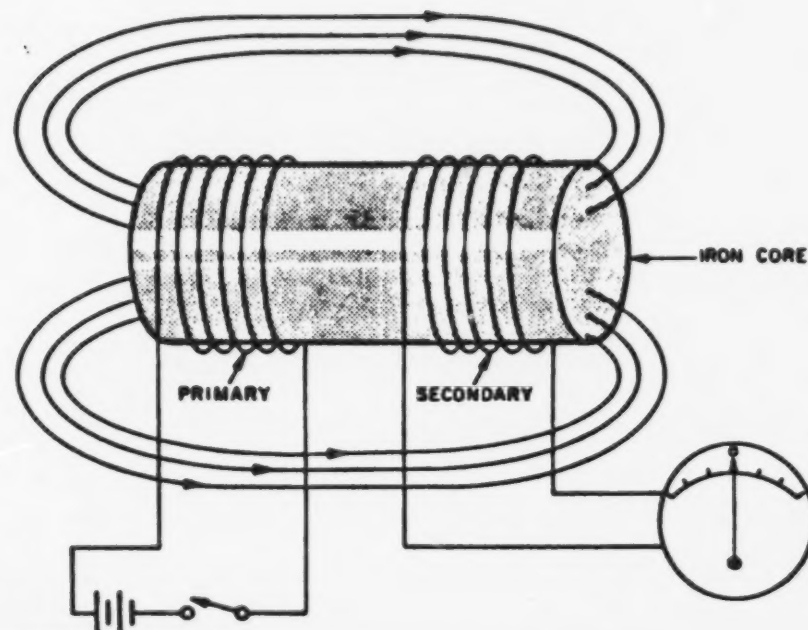
$$L_T = L_1 + L_2 + L_3 + \dots L_N$$

$$L_T = L_1 + L_2 \pm 2M$$

$$\frac{1}{L_T} = \frac{1}{L_1} + \frac{1}{L_2} + \frac{1}{L_3} + \dots \frac{1}{L_N}$$

$$\frac{E_s}{E_p} = \frac{N_s}{N_p}$$

$$N_s = N_p \frac{E_s}{E_p}$$



TITLE: BASIC TRANSISTOR OPERATION

CATEGORY: INNOVATION

DESCRIPTION:

Transistors are made of silicon or germanium material. The silicon or germanium material is doped to produce N or P type semiconductor material. The transistor functions as a current control device and can vary current from near zero to maximum values. The base current controls the collector current in the transistor. Since a very small base current controls a larger collector current, the transistor can function as an amplifier.

SCIENCE CONCEPTS:

1. Semiconductors are materials that have a resistivity that is in the range between conductors and insulators.
2. Transistors are examples of semiconductors.
3. A transistor is, generally, composed of the element Silicon or Germanium.
4. Covalent bonds are formed when atoms share electrons.
5. The covalent bonds, formed by Silicon or Germanium atoms, create a crystal lattice form.
6. The Silicon or Germanium lattice works are "doped" with an impurity coating, to give the transistor its conductive characteristics.
7. Two categories of impurity coatings are trivalent and pentavalent coatings.
8. Common trivalent impurities include Aluminum, Gallium, Indium, and Boron.
9. Common pentavalent impurities include Arsenic, Bismuth, Antimony, and Phosphorus.
10. A trivalent impurity leaves free electrons. It is called a Donor Impurity.
11. A pentavalent impurity leaves positive "holes." It is called an Acceptor Impurity.
12. A transistor is composed of three sections. The first section is the Emitter, the second is called the Base, and the final section is named the Collector.
13. Transistors have two junctions or interfaces between different types of matter.
14. The Law of Charges explains the flow of current through a transistor.
15. Transistors will allow a small current to control a large current.

TITLE: BASIC TRANSISTOR OPERATION

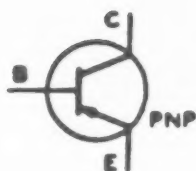
CATEGORY: INNOVATION

MATHEMATICAL CONCEPTS:

1. Collector current is directly proportional to base current.
2. Computation of β or h_{fe} , the current gain for a common-emitter transistor amplifier circuit.

$$\beta = \frac{\Delta I_c}{\Delta I_b}$$

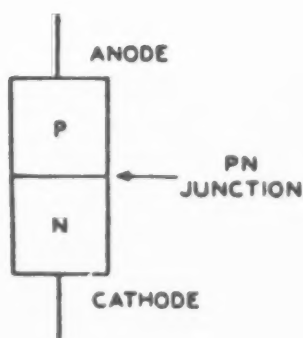
Δ means change
 I_c = collector circuit current
 I_b = base circuit current



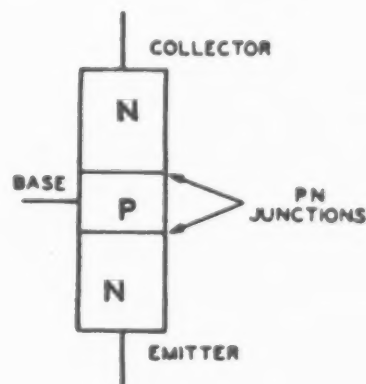
BASIC TRANSISTOR OPERATION



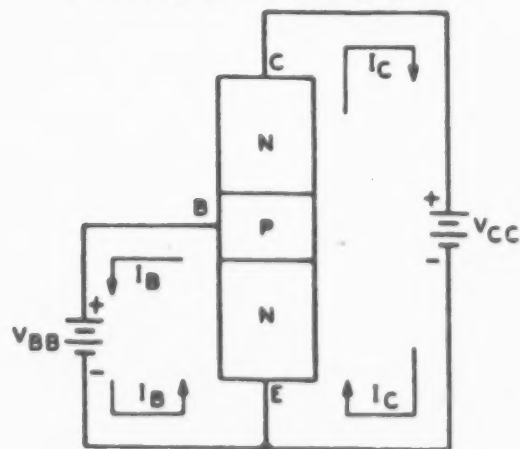
DIODE



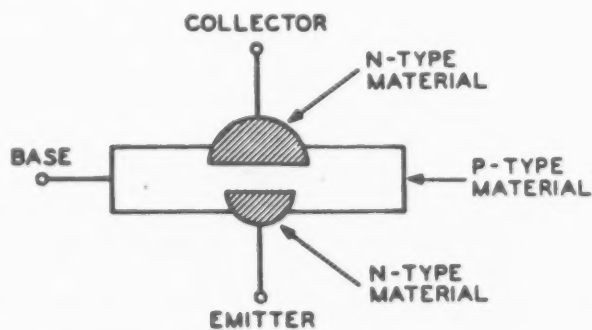
NPN TRANSISTOR

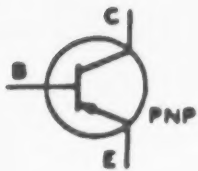


CURRENT FLOW

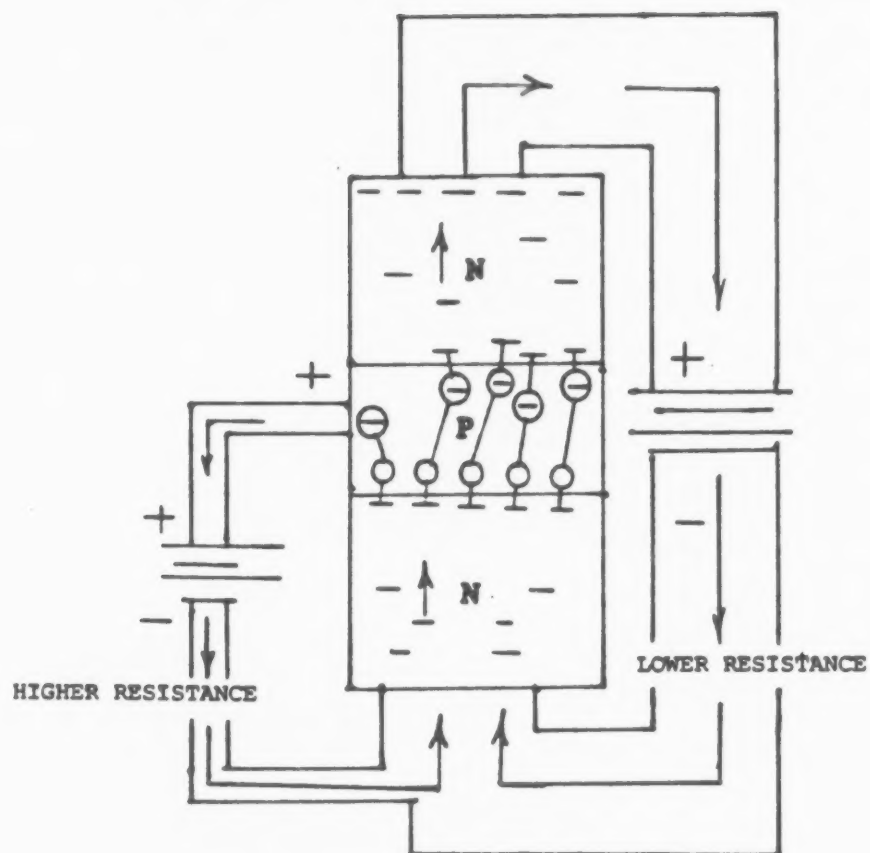


CONSTRUCTION





BASIC TRANSISTOR OPERATION



TITLE: TURBOCHARGER

CATEGORY: TOOLS AND MACHINES

DESCRIPTION:

The power an engine produces is directly proportional to the mass of air the engine uses. At full throttle an engine will take as much air as the atmosphere can push in. The amount of air going into an engine can be increased by blowing air into the engine under pressure. This can be done with a mechanically driven blower, called a supercharger. In automobiles it is more common to blow the air into the engine with a turbocharger.

The turbocharger uses some of the energy remaining in the high-temperature exhaust gas to rotate a turbine wheel at high speeds. A centrifugal compressor wheel is on the same rotating shaft as the turbine wheel. The high-rpm compressor increases the amount of air packed into the intake manifold. This increases the pressure and density of the intake charge in the manifold. When the intake valve opens, more of the intake charge can get into the cylinder than would be possible without turbocharging.

Turbocharging increases the amount of intake charge going into the engine. This results in higher pressures during the compression stroke. A small-displacement engine operating in its midrange at cruising speeds will provide maximum fuel economy, but it will have little power left for acceleration and hill climbing. Putting a turbocharger on the small-displacement engine will give the engine the power needed. A small turbocharged engine provides better economy and the same power as a large-displacement engine without turbocharging.

SCIENCE CONCEPTS:

1. Charles' Law states that the volume of a gas increases as its temperature increases, if pressure is held constant.
2. Boyle's Law states that the volume of a gas decreases as its pressure increases, if the temperature does not change.
3. Gay-Lussac's Law states that the pressure of a gas increases as its temperature increases, if the volume is held constant.
4. Combined Gas Law -
$$\frac{V_1 P_1}{T_1} = \frac{V_2 P_2}{T_2}$$
5. Compression ratio is the relationships between the volume of the cylinder when the piston is at the bottom dead center with the volume remaining within the cylinder when the piston is at top dead center.
6. The compression cycle increases the pressure on the air fuel mixture, and as a result the temperature increases.

TITLE: TURBOCHARGER

CATEGORY: TOOLS AND MACHINES

SCIENCE CONCEPTS CONTINUED:

7. The heat released when the spark plug ignites the compressed fuel-air mixture within the cylinder causes the pressure to increase suddenly (Gay-Lussac's Law). This drives the piston downward.

8. Engines change heat energy into mechanical energy.

9. Momentum = mass x velocity

In a turbocharger the momentum of the exhaust gases is transferred first to the turbine and then it is transmitted to the compressor. The compressor accelerates the incoming air. In this way the momentum is transferred to the incoming air. This transfer of momentum from the exhaust gas to the incoming air illustrates the Law of Conservation of Momentum.

10. Centrifugal force is the apparent pull away from the center when a body moves in a circle. Centripetal force is the force that keeps a body moving in a circle. If, at any time, the centripetal force stops acting on a body, it will obey Newton's First Law of Motion. Instead of moving in a line away from the center of the circle, it will move in a straight line that is a tangent to the circle of motion.

TITLE: TURBOCHARGER

CATEGORY: TOOLS AND MACHINES

MATHEMATICAL CONCEPTS:

1. Convert cubic centimeters to cubic inches.
2. Change cubic inches to cubic centimeters.
3. Change liters to cubic inches.
4. Ratio and proportion apply to various situations.
5. Problems using math terms (increase, decrease).
6. Point out the advantages of knowing how to use a formula.

Formula:

$$\frac{V_1 P_1}{1} = \frac{V_2 P_2}{1}$$

$$E = PN$$

$$C = AS$$

$$A = \pi r^2$$

$$r = \frac{1}{2}B$$

$$P = AS$$

cid - engine displacement

cm³ - cubic centimeter

cu. in. - cubic inches

l - liters

V - Initial volume

V₁ - Final Volume
2

t₁ - Time

E - Engine displacement

C - Cylinder displacement

N - Number of cylinder

A - Area of Piston Head

B - Bore

π - Pi

S - Length of Stroke

P₁ - Initial Pressure

P₂ - Final Pressure

1. To convert cubic centimeters to cubic inches, multiply by 0.061 (cc x 0.061 = cu. in. or cid)
2. To change cubic inches to cubic centimeters multiply by 16.39 (cuin or cid) x 16.39 = cc).
3. To change over liters to cubic inches, multiply by 61.02 (liters x 61.02 = cu. in. or cid).

TITLE: TURBOCHARGER

CATEGORY: TOOLS AND MACHINES

MATHEMATICAL CONCEPTS CONTINUED

example:

A 350-cid engine is also a 5736.5 engine.
 $350 \times 16.39 = 5736.5$

If expressed in liters the displacement of the engine would be rounded to 5.7 liters (1 liter = 1000 cc.)

Find the cylinder, displacement an engine displacement of an eight cylinder with a 4 inch bore and a 3.5 inch stroke.

Individual cylinder displacement equals

$$\pi r^2 \times L$$

$$3.1416 \times 2^2 \times 3.5 = 43.98 \text{ cid.}$$

Total displacement = $43.98 \times 8 = 351.84$
total engine displacement 351.8 4 cu. in. Cu. in.

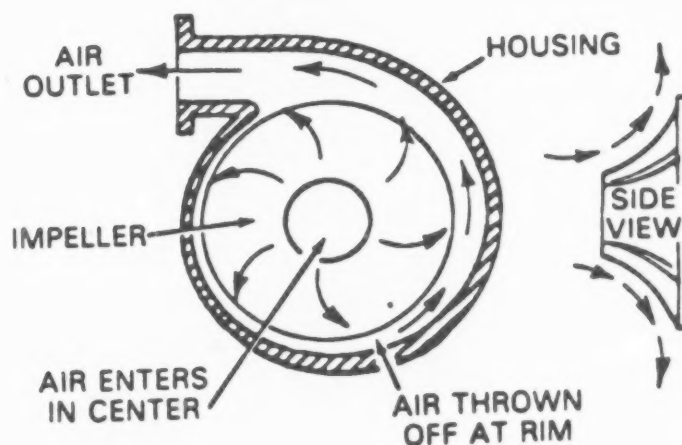
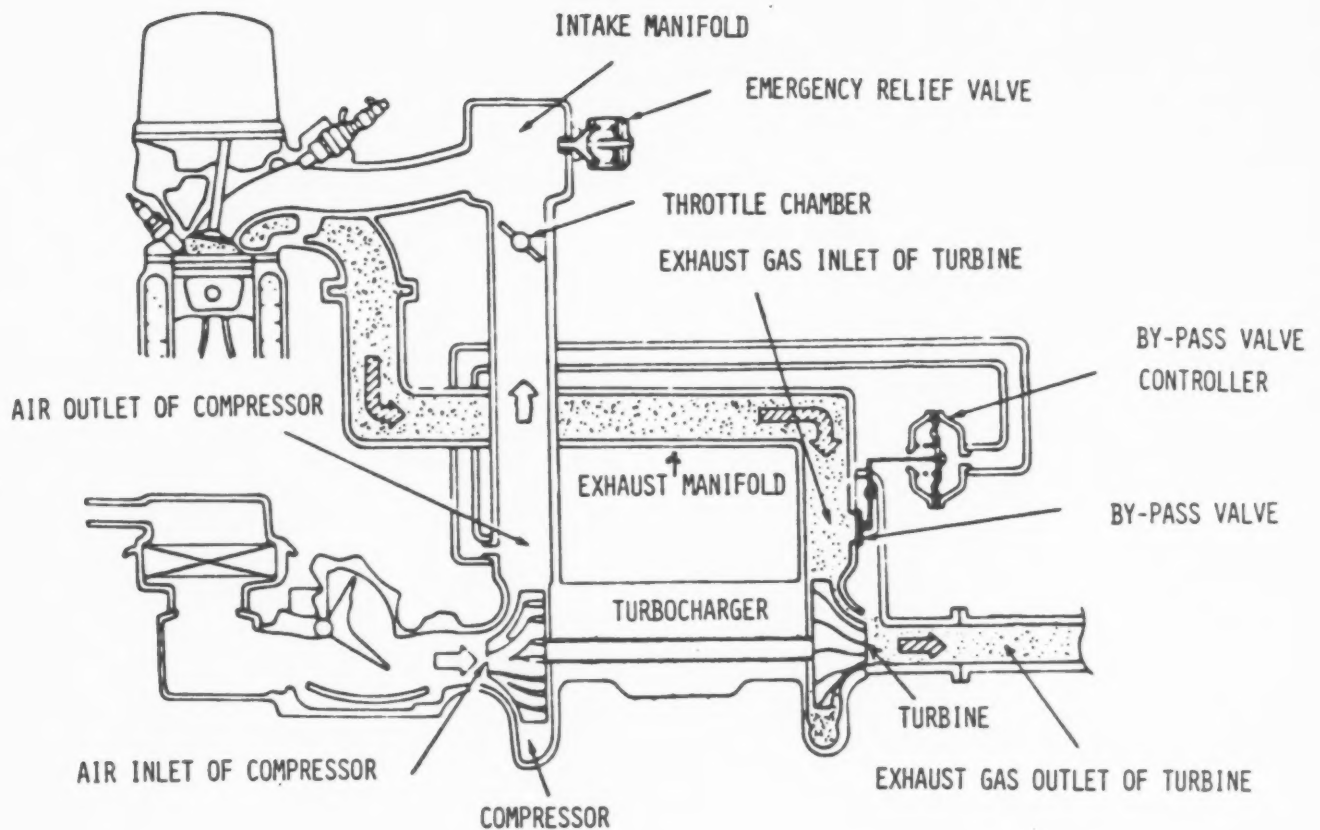
Example:

Find the engine displacement of an engine that has a Bore 8 cm, length of Stroke(s) 7 cm, number of cylinder 6.

$r = \frac{1}{2} B$	$A = \pi r^2$	$P = AS$
$r = \frac{1}{2} \times 8 \text{ cm}$	$A = 3.14 \times 4^2$	$P = 50.24 \text{ cm}^2 \times 7 \text{ cm}$
$r = 4 \text{ cm}$	$A = 50.24 \text{ cm}^2$	$P = 351.68 \text{ cm}^3$

$$\begin{aligned} E &= PN \\ E &= 35.68 \text{ cm}^3 \times 6 \\ E &= 2110.08 \text{ cm}^3 \end{aligned}$$

TURBOCHARGING



TITLE: TWO CYCLE ENGINE

CATEGORY: INNOVATION

DESCRIPTION:

The two stroke engine is used for powering engines that are subjected to continual position change. Examples of such engines are: chainsaws, model airplanes and motorcycles. The fuel for a two stroke engine is composed of a mixture of gasoline and oil. The gas-oil vapor is drawn directly into the piston. This allows the machine to be used in any position and still receive adequate lubrication.

SCIENCE CONCEPTS:

1. Friction--a force opposing motion.
2. Lubricant--any substance that reduces friction.
3. Potential energy--stored energy; energy of position.
4. Kinetic energy--energy in moving things.
5. Compression--squeeze together.
6. Fuel--material that is used to produce heat energy.
7. Ignite--to subject to the action of fire or intense heat.
8. Combustion--combining with oxygen to produce an explosion resulting in heat energy.

MATHEMATICAL CONCEPTS:

$$\text{Horsepower} = \frac{\text{Distance (meters)} \times \text{Force (newtons)}}{\text{Time (min.)} \times 33.00}$$

$$\text{Power} = \frac{\text{Distance} \times \text{Force}}{\text{Time (min.)}}$$

$$\begin{aligned}\text{Engine Displacement} &= V = \pi \times r^2 \times h \\ \pi &= 3.14 \\ r &= \frac{1}{2} \text{ the bore diameter} \\ h &= \text{stroke length}\end{aligned}$$

Stroke--distance from TDC (Top Dead Center) to the piston at ADC (Bottom Dead Center)

Bore--distance across the cylinders

Torque--force x radius

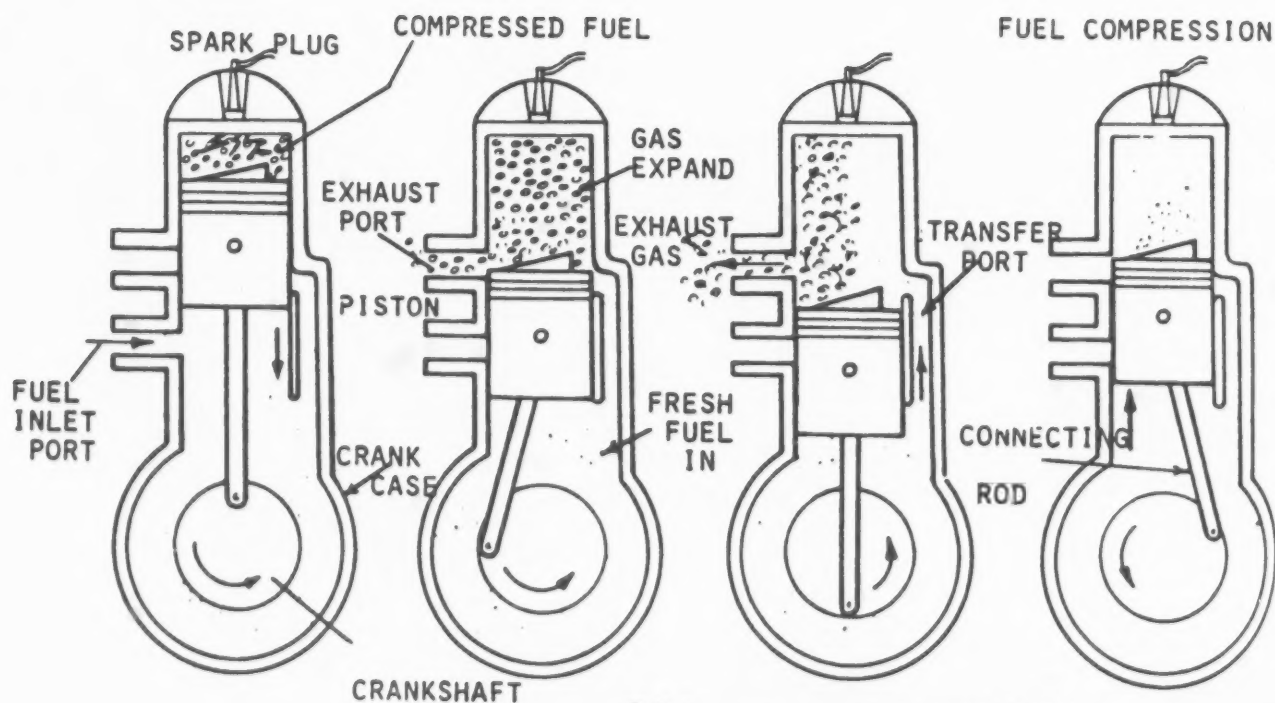
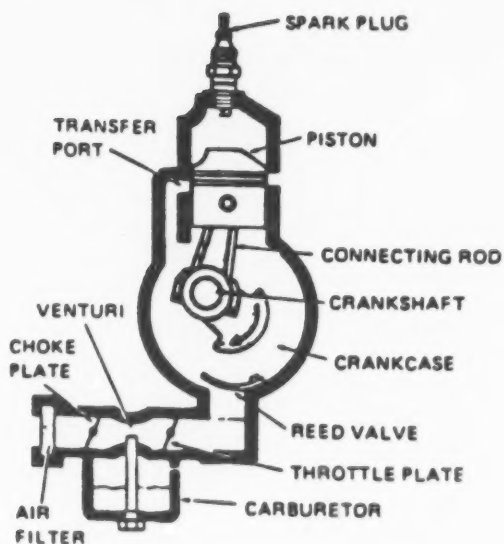
TWO-STROKE ENGINE

SCIENCE CONCEPTS

LUBRICANT
POTENTIAL ENERGY
KINETIC ENERGY
COMPRESSION
FUEL
IGNITE
COMBUSTION

MATH CONCEPTS

HORSEPOWER
ENGINE DISPLACEMENT
STROKE
BORE
TORQUE
POWER



Title: Wind Tunnel

Category: Research and Experimentation

Description:

Today, as never before, there is an increasing need for sophisticated scientific research to solve existing technological problems and to create opportunities to develop new products for the future. Wind tunnel testing is extremely crucial to the research, design, and development of products and/or processes subjected in any way to the forces of wind motion. Scientists and engineers increasingly rely on wind tunnel research to provide the data they need to solve key technological problems. Applied aerodynamic research can be the answer to achieving efficiency of design, safety, and performance.

Title: Wind Tunnel

Category: Research and Experimentation

Science Concepts:

- (1) Wind tunnel - a device which provides an airstream of known and steady conditions in which models requiring aerodynamic study are tested.
- (2) Wind - a movement of air of any velocity. (Wind is produced by the sun heating the air above the earth unevenly. As warm air rises, the cooler air rushes in to take its place.)
- (3) Atmosphere - the whole mass of air surrounding the earth (air pressure at sea level = 14.7 pounds per square inch).
- (4) Aerodynamics - a branch of the science of physics that deals with the motion of air and other gaseous fluids and the forces acting on bodies in motion relative to such fluids.
- (5) Pressure - force applied per unit of area.
- (6) Lift - the upward force that opposes the pull of gravity. (It reduces the frictional forces between the tires and the road surface. This has an effect on car stability.)
- (7) Resistance - any opposition which slows down or prevents motion.
- (8) Velocity - the speed and direction of a moving object.
- (9) Drag - the retarding force acting on a body (as a metric dragster) moving through a fluid (such as air) parallel and opposite to the direction of motion. (In a real car this affects fuel consumption.)
- (10) Inertia - the tendency of matter to remain at rest or in uniform motion unless acted on by a force.

Additional Information

An increase in lift reduces the rolling resistance of a car (friction between tires and the road) and increases its speed.

Title: Wind Tunnel

Category: Research and Experimentation

Science Concepts:

Increased lift, however, affects maximum tractive force in a negative way.

By careful design and styling, which reduces engine power requirements, we can save one million gallons of fuel a year.

Drag affects acceleration in a negative way. Reduced drag makes reaching certain speeds easier (and aids passing a car).

Aerodynamic down force (or negative lift force) improves road holding. In racecars, particularly, this has permitted higher speeds in turns. (Cars hold to the road.)

Environmental Impact

Particularly since the oil embargo the American automobile industry has concentrated its attention on designing cars that are more fuel efficient. (In Europe and other parts of the world fuel efficiency was a concern long before.) This was due to the doubling, then tripling of pump prices for gasoline. In addition pressure continued to mount from the environmentalists desiring a reduction in the harmful emissions from automobile exhausts. The E.P.A. (Environmental Protection Agency) brought to the public's attention the effects on air quality that automobile emissions have. As a result cars were designed aerodynamically. Changes in body styling, size, and fuel efficiency resulted.

Social Impact

Americans have changed their consumer attitudes regarding the qualities they sought in a new car. No longer did the average American regard the large luxury car (gas guzzler) as a necessary status symbol. Instead fuel efficiency became a selling point and smaller cars become more acceptable, indeed desirable.

Title: Wind Tunnel

Category: Research and Experimentation

Mathematical Concepts:

- (1) Measurement of metric weight (grams, milligrams)
- (2) Knowledge of division of decimals
- (3) Knowledge of changing decimals to percent
- (4) Concept of positive and negative numbers for measurement of drag
(in case less efficient)
- (5) Simple efficiency formula
$$\text{efficiency} = \frac{\text{change in drag (metric weight measure)}}{\text{original drag (metric weight measure)}}$$
 - a) if drag measure increases then less efficient
 - b) if drag measure decreases then more efficient
- (6) Convert simple formula for efficiency to percent of change formula
$$\frac{\text{change in drag}}{\text{original drag}} = \frac{\%}{100}$$
- (7) Actual aerodynamic drag formula is $D = C_D A \frac{P}{2} V^2$

where D = aerodynamic drag

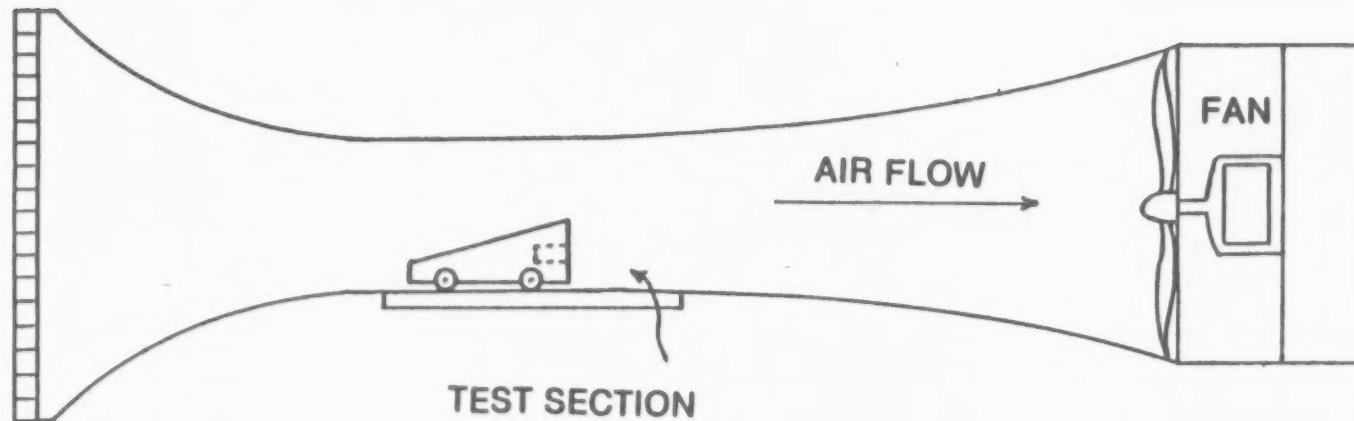
C_D = the non-dimensional drag coefficient

A = total front area

P = density of surrounding air

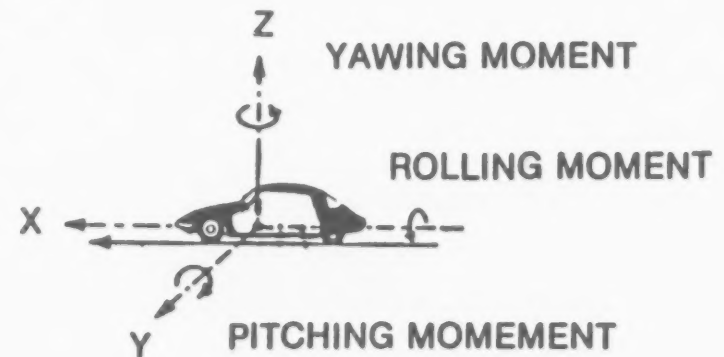
V = velocity
- (8) Ability to read and plot tables and graphs to show results of tests.

WIND TUNNEL



SIMPLE EFFICIENCY FORMULA

$$\frac{\text{CHANGE IN DRAG}}{\text{ORIGINAL DRAG}} = \text{EFFICIENCY}$$



WIND TUNNEL: A DEVICE WHICH PROVIDES AN AIRSTREAM IN WHICH OBJECTS REQUIRING AERODYNAMIC STUDY ARE TESTED.

TITLE: Wind Turbine

CATEGORY: Innovation

DESCRIPTION:

A wind machine usually consists of a large rotating blade, like an airplane propeller. The air molecules making up the wind collide with this blade, give up some of their momentum and energy to it, and cause it to rotate at high speed. A wind turbine can be used to convert the available in the wind by changing its kinetic energy into mechanical or electrical energy that can do work. An electric generator can be set up by using the rotating shaft of the wind machine as the armature of the generator and applying an electric field from an external source. The mechanical energy of the rotating shaft is converted into electrical energy as the armature rotates in the field.

SCIENCE CONCEPTS:

1. BERNOULLI'S PRINCIPLE: IF A FLUID IS MOVING ALONG A SURFACE, THE FLUID WILL CAUSE A FORCE ON THAT SURFACE. THIS FORCE WILL BE PERPENDICULAR TO THE SURFACE. IF THE FLUID MOVES FASTER, IT WILL CAUSE LESS FORCE ON THE SURFACE.
2. LIFT - UPWARD FORCE OF AIR MOVING AROUND AN OBJECT.
3. INCREASE LIFT BY:
 - A. INCREASING THE SURFACE OF THE BLADE
 - B. INCREASING THE ANGLE OF ATTACK
4. DRAG - FRICTION CREATED WHEN OBJECTS MOVE IN AIR.
5. FRICTION- A FORCE THAT ACTS TO SLOW DOWN A MOVING OBJECT THAT IS PASSING THROUGH OR AGAINST A MATERIAL. A FORCE IS A PUSH OR A PULL.
6. SIMPLE MACHINE - A DEVICE THAT HELPS YOU DO WORK BY INCREASING FORCE, INCREASING SPEED, OR CHANGING THE DIRECTION OF THE FORCE,
WHEEL AND AXLE- A SIMPLE MACHINE THAT IS A TYPE OF LEVER,
LEVER AND FULCRUM- A BAR OR BOARD THAT IS FREE TO PIVOT ABOUT A FIXED POINT CALLED THE FULCRUM.
GEARS- A KIND OF WHEEL-LIKE MACHINE THAT ACTS LIKE A LEVER.
7. WORK IS THE RESULT OF A FORCE ACTING ON A BODY AND MOVING IT THROUGH A DISTANCE.
8. ENERGY IS NEEDED FOR WORK TO BE DONE.
9. ENERGY CONVERSION OCCURS AS ENERGY IS BEING TRANSFERRED FROM KINETIC TO MECHANICAL ENERGY.

SCIENCE CONCEPTS:

10. WIND IS PRODUCED BY THE SUN HEATING THE AIR ABOVE THE EARTH UNEVENLY; AS THE WARM AIR RISES, COOLER AIR RUSHES IN TO REPLACE IT.
11. WIND IS A RENEWABLE SOURCE OF ENERGY.
12. THE ESSENTIAL PARTS OF A LARGE ELECTRIC GENERATOR ARE LARGE ELECTROMAGNETS, COILS OF WIRE, AND A SOURCE OF ENERGY TO TURN THE COILS OF WIRE IN THE MAGNETIC FIELD.
13. A MAGNETIC FIELD IS SAID TO EXIST IN A REGION WHERE MAGNETIC FORCES CAN ACT.
14. ELECTROMAGNETIC INDUCTION IS THE PRODUCTION OF AN ELECTRIC CURRENT BY A CHANGING MAGNETIC FIELD.

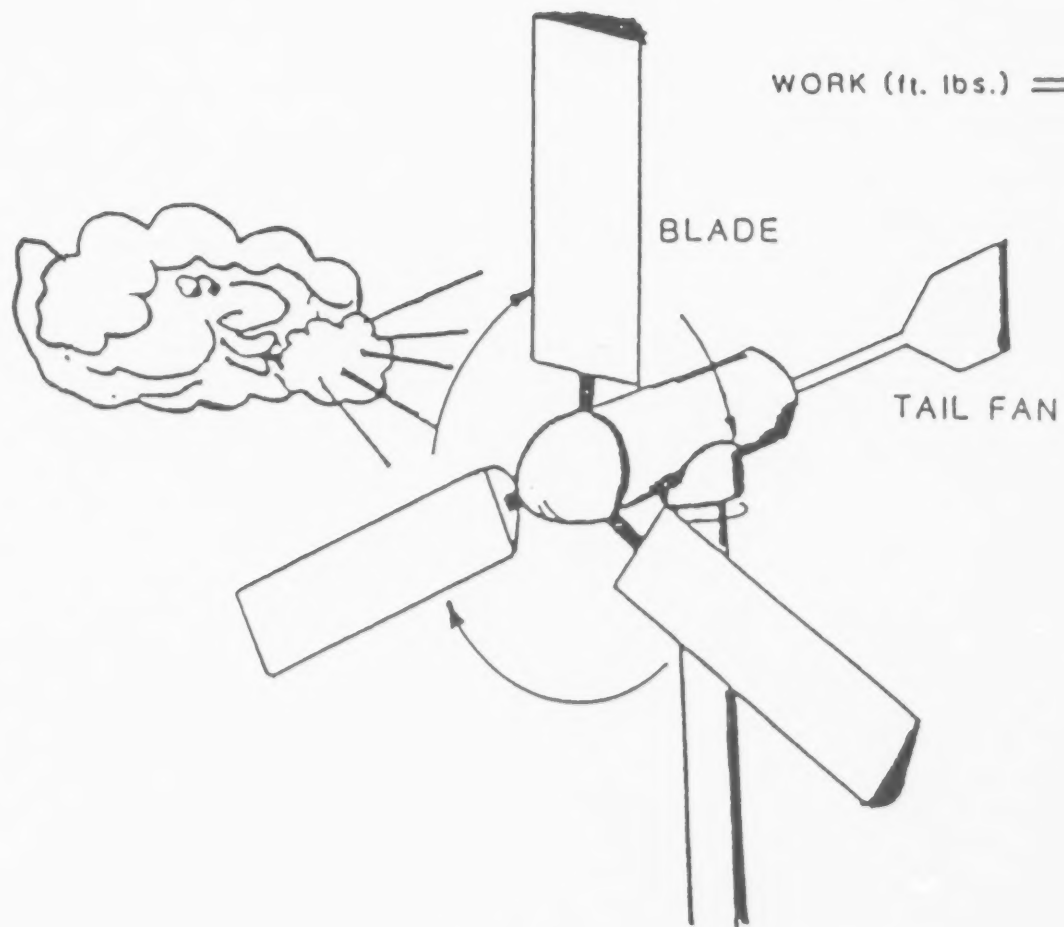
TITLE: WIND TURBINE

CATEGORY: INNOVATION

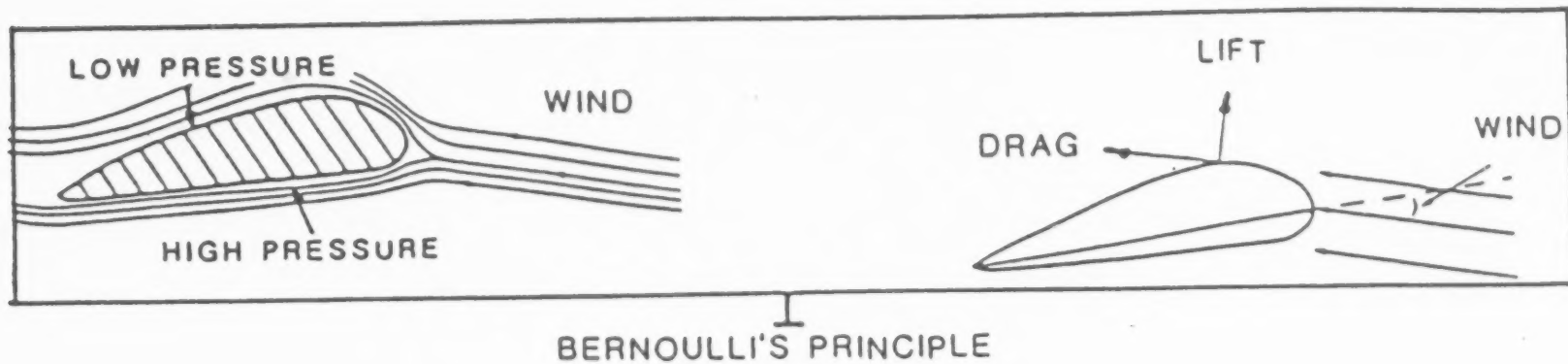
MATH CONCEPTS:

1. $L = v\Delta T$ DISTANCE = VELOCITY x TIME
 ΔT = TIME WHICH KINETIC ENERGY IS TRANSMITTED TO THE BLADES
2. $V = AL$ VOLUME OF AIR = AREA OF BLADES x DISTANCE
VOLUME OF AIR = $A \cdot \bar{v}^2 \cdot \Delta T$ x DISTANCE
SUBSTITUTING: $V = Av\Delta T$
3. $M = dV$ MASS = DENSITY x VOLUME
SUBSTITUTING: $M = dAv\Delta T$
4. $P = \frac{1}{2}dAv^3$ POWER = $\frac{1}{2}$ x DENSITY x AREA x VELOCITY³
5. MULTIPLICATION OF DECIMALS
6. MULTIPLICATION OF FRACTIONS
7. EXPONENTS
8. TORQUE (NEWTON-METER) = LEVER ARM x FORCE
9. UNIT OF WORK $W = F \times D$
10. HEAT / WORK $W = J \times H$
 W = WORK DONE (FT. x LBS.)
 H = HEAT (B.T.U.)
 J = JOULE'S EQUIVALENT (777.8)
11. POWER (Hp.) = $\frac{\text{FORCE} \times \text{VELOCITY}}{33,000}$
12. ORDER OF OPERATIONS

WIND TURBINE

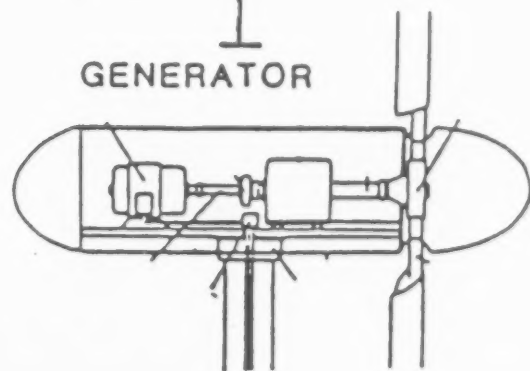


WIND TURBINE

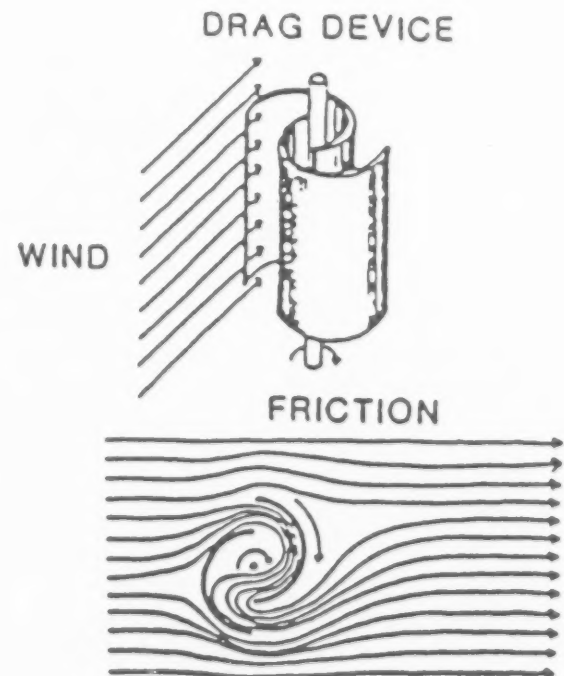
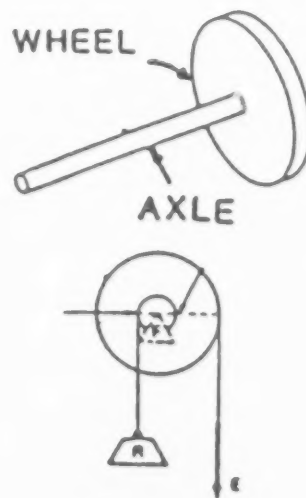


ELECTROMAGNETIC INDUCTION:

$$V = N \times \frac{\text{CHANGE IN FLUX}}{\text{CHANGE IN TIME}}$$



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TITLE: WOODBURNING STOVES

CATEGORY: INNOVATION

DESCRIPTION:

A furnace commonly made of cast iron, sheet iron, or sheet steel is especially designed to use wood, a renewable resource, as fuel. It provides heat by means of conduction, convection, and radiation.

SCIENCE CONCEPTS:

1. Heat is that energy which is transferred between two systems by virtue of a temperature differential.
2. Heat is produced when fuels such as wood enter into chemical action with oxygen.
3. Heat energy can be transferred by three different methods, which are convection, conduction and radiation.
4. Convection is where the heat is carried from one point to another by actual movement of the hot material.
5. Conduction is where heat must diffuse through solid materials or through stagnant fluids.
6. Radiation is where heat is transferred by means of radiant wave energy.
7. Energy is the capacity for doing work.
8. Potential energy is energy a body possesses by virtue of its location or configuration.
9. Kinetic energy is energy a body possesses due to its motion.

TITLE: WOODBURNING STOVES

CATEGORY: INNOVATION

MATHEMATICAL CONCEPTS:

1. Heat exchange

$$Q_{\text{lost}} = Q_{\text{gained}}$$

Q_{lost} = quantity of heat lost

Q_{gained} = quantity of heat gained

2. Potential energy

$$\text{P.E.} = mgh$$

or

$$\text{P.E.} = wh$$

m = mass

g = acceleration of gravity

h = vertical distance

w = weight

3. Kinetic energy

$$\text{K.E.} = \frac{1}{2}mv^2$$

or

$$\text{K.E.} = \frac{1}{2} \frac{wv^2}{g}$$

m = mass

v = velocity

w = weight

g = acceleration of gravity

4. Thermal conductivity is the ratio of heat flow to temperature gradient.

$$q = K \frac{\Delta t}{\Delta x}$$

q = heat flow or flux

K = thermal conductivity

Δt = change in time

Δx = change in area

5. Fourier's Law--the amount of heat transferred by conduction.

$$Q = \frac{KA \Delta T}{L}$$

Q = heat transferred per unit time

A = area perpendicular to the heat flow through which it is passing

L = thickness of the body of matter through which the heat is passing

ΔT = temperature difference

K = conductivity constant dependent on the nature of the material and its temperature

6. Stephan-Boltzmann Law--the amount of heat transferred by radiation.

$$Q = bA(T_1^4 - T_2^4)$$

Q = amount of heat transferred per unit time

b = constant

A = area of radiating surface

T_1 = absolute temperature of the radiating body

T_2 = absolute temperature of the receiving body

7. For transfer of heat by convection.

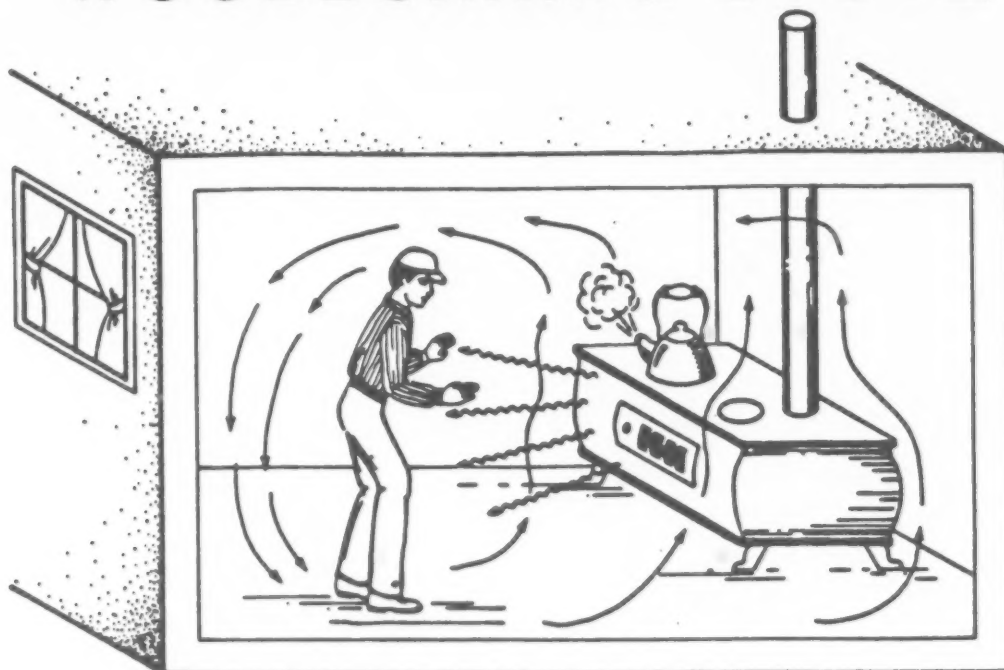
$$Q = hA \Delta T$$

Q = heat transferred per unit time

A = area through which it is being transferred

ΔT = temperature difference across the material through which the heat is flowing

WOODBURNING STOVE



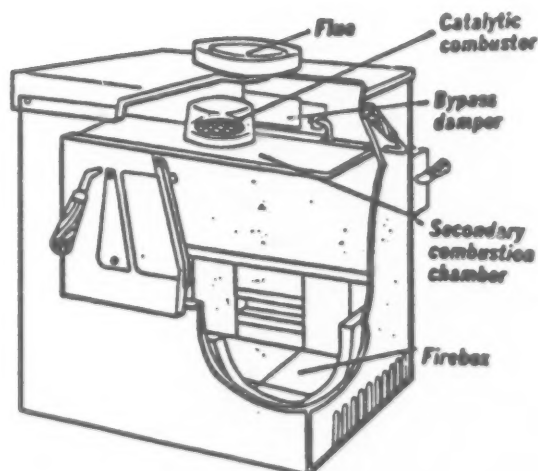
HEAT TRANSFER BY CONDUCTION, CONVECTION, AND RADIATION.

MATH CONCEPTS

FORMULA INTERPRETATION AND USE

SOLVING FOR A PARTICULAR VARIABLE

USE OF APPROPRIATE UNITS OF MEASUREMENT



SCIENCE CONCEPTS

ENERGY TRANSFER

HEAT

CONDUCTION

CONVECTION

RADIATION

POTENTIAL ENERGY

KINETIC ENERGY